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**FLUID AMPLIFIER STATE OF THE ART**

**VOLUME II - BIBLIOGRAPHY**

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**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

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## INTRODUCTION

31700

This bibliography was prepared by the General Electric Advanced Technology Laboratories under NAS 8-5408, sponsored by the Marshall Space Flight Center.

The search was limited to no-moving part fluid devices and representative sources for basic technology. The search was assisted by the NASA Documentation Center and the Defense Documentation Center. The period from 1935 to the present was covered. Particular effort was made to find references in the Russian literature in view of reports that the fluid devices are being applied in their missiles.

The bibliography includes 317 references, of which 210 have been abstracted. No appreciable effort was identified in the period from 1935 until early 1960; most of the references have appeared during the last two-and-a-half years. There was almost no specific information on Russian progress in the field.

The bibliography is organized to present references by author in alphabetical order. A subject index is also given (page vi) with cross-reference identifications to the author index. Volume II includes only the unclassified references; classified items are in Volume IV.

The sources of information searched were:

Aeronautical Engineering Index  
Aerospace Engineering Index  
Aerospace Engineering Reviews and International  
Aero Abstracts  
Annual Index of Journal of Fluid Mechanics  
Applied Mechanics Review  
Applied Science and Technology Index  
ASTIA  
Battelle Technical Review Abstracts  
Chemical Abstracts  
CIA Reports (Translations)  
Engineering Index  
General Electric Company - Main Library Card File  
General Electric Company - Patent Office  
General Electric Company - Technical Data Center  
Index of NASA Technical Publications  
Index of NASA Technical Publications  
International Aerospace Abstracts  
Monthly Catalog of Russian Accessions  
NASA Technical Publications Announcements  
National Conference of Industrial Hydraulics  
Nuclear Science Abstracts  
Russian Patent Abstracts (General Mechanical and Electrical)  
Science Abstracts (A) Physics  
Translation Monthly  
U. S. Government Research Reports

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A-001

Aizerman, M., Tal', A.

NEW DEVELOPMENTS IN PNEUMOAUTOMATION

International Federation on Automatic Control presented September 1963,  
Zurich, Switzerland

Description of the following engineering features: (1) use of lower working pressures; (2) synthesis of pneumatic devices and systems from basic components using "printed circuit" assembly techniques; (3) design and construction of pneumatic components employing direct interactions of fluid jets (without any intermediate moving parts) and employing a "printed circuit" technique to produce intricate profiles needed to control interaction of the jets.

A-002

Albertson, M. J.

THE DIFFUSION OF SUBMERGED JETS

Transactions of the American Society of Civil Engineers, Vol. 115, 1950

A-003

Albertson, M. L. Dai, Y. B., Jensen, R. A. and Rouse, H.

DIFFUSION OF SUBMERGED JETS

Proceedings ASCE, Vol. 74, Part 2, Page 1571

A-004

Allen, C. W., Knight, H.

ELECTRO-PNEUMATIC TRANSLATOR

U. S. Patent No. 3,072,147

This invention relates to electro-pneumatic translators and, more specifically, to such a translator device characterized by a novel arrangement for proportioning the degree of fluid pressure delivered thereby to the degree of electrical energization of the translator device. This invention is particularly useful for apparatus characterized by both electrical and fluid pressure operable components which are functionally interrelated.

A-005

Anderson, A. R. and Johns, F. R.

CHARACTERISTICS OF FREE SUPERSONIC JETS EXHAUSTING INTO QUIESCENT AIR

Jet Propulsion, Vol. 25, Jan. 1955, No. 1

A-006

Anderson, N. A.

PNEUMATIC CONTROL MECHANISMS

Instruments and Control, Volume 36, No. 2 - Feb., 1963 - Page 113

A discussion of the basic pneumatic control mechanism--the flapper-nozzle element. The flapper-nozzle unit with amplifying relay and feedback billows is a simple rapid-acting, multi-control-mode mechanism.

A-007

Anonymous

A NEW ROLE FOR PNEUMATICS

Automatic Control, Vol. 13, No. 6, Page 11, Dec., 1960

Significant progress in the new use for pneumatics. Intensive development of pneumatic switching and amplifying techniques are underway in Russia. More than 20 companies have initiated R and D projects since March 1960. Non-government funds being spent average \$100,000-\$200,000 per month.

A-008

Anonymous

DIGITAL HYDRAULIC SERVO

Product Engineering, Vol. 34, No. 9, Page 58, April 29, 1963

Actuator accepts digital control signals directly--no need for digital-to-analog converters. It operates on a wide range of fluids, is insensitive to acceleration, vibration and thermal transients.

A-009

Anonymous

FLUID COMPUTING ELEMENTS OPEN NEW DOORS IN CONTROL

Control Engineering, Vol. 7, No. 5, Pages 26-30, May, 1960

Diamond Ordnance Fuze Lab calls its new device a fluid amplifier. You can add, subtract and multiply by combining the devices. It is possible to build a variety of functional and logic devices such as AND and OR units, oscillators, flip-flops and reaction controls.

A-010

Anonymous

FLUID FLIP-FLOP

Technological Digests, July-Aug., 1962, Vol. 7, No. 7-8, Pages 15-16

Fluid-powered counterparts of electronic digital circuits provide attractive alternates for high-temperature applications where only moderate computing speeds are needed. DOFL has been using units in 1 to 5" squares, but much smaller sizes will eventually be built for compactness and higher computing speeds.

A-011

Anonymous

FLUID LOGIC IN CONTROL

Measurement and Control, Vol. 2, No. 4, Page 148, April, 1963

All of the fluid logic devices mentioned are based on the same broad principle: a pneumatic or hydraulic input jet is used to modify the characteristics of a pneumatic or hydraulic fluid stream (which provides the output signal) or to direct this stream from one output channel to another. The means of doing this are either mechanical, using moving or deformable parts, or non-mechanical, using the interaction of the fluid jets and stream.

A-012

Anonymous

FLUID SWITCHES STUDIED FOR USE IN COMPUTERS

Science News Letter, 84:34, July 20, 1963

A new type of switch flipped off and on by liquids or gases is under study for use in computers and control devices. The switch would replace electronic ones that break down under high temperatures and heavy radiation.

A-013

Anonymous

#### FLUID SYSTEMS OPERATE WITHOUT MOVING PARTS

Automatic Control, Vol. 12, No. 4, Pages 15-19, April, 1960

Principles first demonstrated before the turn of the century have been incorporated in a new family of fluid-actuated systems, which in some applications perform control functions more economically and reliably than their electronic counterparts. This technique can be used in the design of amplifiers, counters, logical operation devices and time internal regulators.

A-014

Anonymous

#### FUTURE FOR FLUID AMPLIFIERS

Electronics, Vol. 33, No. 13, Page 41, March 25, 1960

Army discloses new device which uses gas and liquid pressures instead of voltages. Unit can perform amplification, feedback, digital computation, analog computation. Inventors: B. M. Horton, R. E. Bowles, R. W. Warren (DOFL).

A-015

Anonymous

#### GENERAL-PURPOSE FLUID LOGIC INSTRUMENT

Measurement and Control, Vol. 2, No. 4, Page 150, April, 1963

One of the first pieces of fluid logic hardware is a general-purpose instrument which can be used for experiments or development work on digital information processing. This instrument, called a Turbulence Amplifier Console, measures 8" by 9" by 8", contains an assembly of 24 NOR logic units, means for interconnecting these units by flexible tubing, a built-in pump and manifold for supplying air to the units, and nine manometers for monitoring air pressure signals and the supply pressure.

A-016

Anonymous

LEWIS PUSHES NERVA AND LOOKS AHEAD

Control Engineering, June 1963, Vol. 10, No. 6, Page 20

Startup in space of a boot strapping regeneratively cooled nuclear engine is a formidable problem in dynamic analysis and control. NERVA will use specialized versions of proven technology, but next-generation rockets are already under study. A new laboratory will evaluate pneumatic elements for computing and actuation.

A-017

Anonymous

LOGICAL PRESSURE

Research for Industry, Vol. 15, No. 2, published by Stanford Research Institute, March-April, 1963

A new element using tiny spheres has been devised that acts like an electronic NOR logic device. These NOR devices can be readily interconnected to perform all the fundamental logic functions required for digital computing: AND, OR, NOT, and memory. Preliminary studies show that units using one or two spheres can be combined in circuits to perform either as a constant gain amplifier or one having an adjustable negative pressure gain. This may lead to a unique analog type computer.

A-018

Anonymous

MOVING BALL COMPUTERS WITH AIR

Control Engineering, Pages 22-23, July, 1961

New bi-stable element has demonstrated all the necessary functions of arithmetic and logic required in a digital computer. It can be miniaturized so that component densities from 2000 to 4000 units per cu. in. are possible. Next step--to build a pneumatic computer with elements (Kearfott).

A-019

Anonymous

#### NEW FLUID AMPLIFIER PRINCIPLE DEMONSTRATED

Control Engineering, Page 21, November 1962

Star of the show at a government-industry meeting on fluid amplifiers, held by DOFL, was an extremely simple amplifying device, called the "turbulence amplifier" by inventor R. N. Auger. The new device is a small diameter tube that directs a laminar jet of air or other fluid into a receiving tube of like cross-section about an inch away. A lower-pressure control jet at a right angle breaks the laminar main flow into turbulence, reducing the mass flow of air entering the receiving tube and the output pressure produced. Pressure gains of seven and power gains of several hundred are practical.

A-020

Anonymous

#### NOW A BALL TYPE FLUID DIGITAL COMPUTER

Automatic Control, Vol. 15, No. 2, August, 1961

A new fluid digital computer component design has been revealed by Kearfott. Component packing densities are estimated at up to 4000 switching elements per cubic inch. This brings the number of devices introduced into the field to four during the last twelve months. (Previous entries in order of publication, were designs by DOFL, Inst. of Automatics, and Telemechanics, and IBM, Zurich) Application - Nav. and Guid. Computers, Gen. purpose digital computers, business machines.

A-021

Anonymous

#### PNEUMATIC COMPUTER RESEARCH IN THE USSR

Automatic Control, Vol. 13, No. 6, Dec., 1960

Nearly all of the components described in this article are actually in the advanced research stage. Structurally they are relatively simple and could be manufactured with conventional techniques. Transition from Lab to Industrial Application may be rapid.

A-022

Anonymous

#### PNEUMATIC COMPUTER SUITABLE FOR SPACE

Aviation Week, Vol. 74, No. 23, Pages 81-85, June 5, 1961

Pneumatic digital computer under development by Kearfott will employ tiny gas operated flip-flops. Company says that approximately 3,000 pneumatic flip-flops and their interconnecting "circuitry" and power supply can be built into a one-inch cubic inch package.

A-023

Anonymous

#### PNEUMATIC CONTROL SYSTEMS

Engineers Digest, Vol. 22, No. 8, August, 1961

During the first decade of numerical control, electronics undoubtedly reigned supreme, but with the recent advances in pneumatic bi-stable state devices, there has been an increasing urge to design a non-electronic machine-tool system. So far, there appears to be only one such system that developed by Morg Servo Controls, Inc. and described by E. C. Brown in his paper "A Pneumatic-Hydraulic Approach to Point-to-Point Positioning."

A-024

Anonymous

#### PNEUMATIC DIGITAL COMPUTER

Electromechanical Design, Pages 36-40, June, 1961

Pneumatically operated devices have generally been considered inherently bulky, slow in operation, and useful primarily where the output is a relatively large amount of mechanical work. Kearfott engineers under the direction of Hugh E. Riordan have found, however, that by accepting only the limitations imposed by physical laws and current fabrication technology they can build compact pneumatic devices with response times comparable to those of many electronic and electrical components.

The article continues to discuss pneumatic computer advantages, tolerance requirements, construction and packaging, etc.



A-025

Anonymous

**PNEUMATIC RATIO TOTALIZER RELAY**

The Engineers Digest, Vol. 22, No. 9, Page 109, Sept., 1961 (British)

A new ratio totalizer relay, introduced by Hogan Controls, Ltd. of London, S. W. 1, has been specially designed for use in a control system employing one or more flow-signal transmitters and a pressure transmitter. In its standard form, this relay can perform simple addition, subtraction, comparison, multiplication, division, and averaging of two input signals. Furthermore, it can provide control action with or without integral (reset) action, derivative (rate) control action or when used in pairs, can select the higher or lower of two input pressures.

A-026

Anonymous

**PNEUMATIC SYSTEMS FOR THE TRANSMISSION OF HEAT AND POWER IN AIRCRAFT**

The Engineers Digest, Vol. XVII, No. 4, April, 1956

According to the Ryan Aeronautical Co., who have devoted a concentrated research program to pneumatic directing, pneumatic systems for the transmission of heat and power, offer the latest and most promising solution to the growing demands of accessories in aircraft. The high speeds, high altitudes, and extended ranges of modern aircraft necessitate minimum structural weight and increased propulsive power. At the same time, requirements for auxiliary power are rising because of increased pressurization, air conditioning, automatic operation, etc.

A-027

Anonymous

**PNEUMATICALLY OPERATED X-RAY SHUTTER**

Technological Digest, Vol. 8, No. 6, Page 67, June, 1963

This apparatus was developed for making absolute x-ray dosage measurements and for calibrating x-ray dosage measuring equipment. Developed by Technical Services, Dept. of CSIR, Pretoria, South Africa.

A-028

Anonymous

#### PROPOSE FLUID LOGIC SPACE COMPUTERS

Electronics, Page 24, March 2, 1962

Fluid Logic Proposed for Space Computers Switching Theory Symposium is told that hydraulic systems using gas and ceramic parts would resist high temperature and radiation. Miniature fluid circuits are now being designed.

A-029

Anonymous

#### VERSATILE PNEUMATIC LOGIC CIRCUITS

Automation, Vol. 9, No. 12, Page 13, Dec., 1962

Advances continue to be made in the development of pneumatic logic components. Bowles Engineering is currently evaluating application opportunities for a line of components that are based upon the ability of a fluid stream to exhibit a bi-stable flow condition. Useful logic circuits are formed from a combination of various basic designs etched in plates (functions such as Flip-Flops or NOR, AND, Inverters and Memory can be obtained from the designs).

A-030

Apstein, M.

#### NOTE ON THE PNEUMATIC AMPLIFIER

Book--Microminiaturization (Proceedings of the AGARD Conference, July 24-26, 1961)

The pneumatic amplifier, or fluid amplifier, as it is sometimes known, is really a deflection amplifier using gas or liquid as the control fluid. The power stream can be deflected so that the orifice is ON or OFF, with feedback, it can be held in either position and is, therefore, equivalent to an electronic Eccles-Jordan flip-flop circuit.

A-031

Aronson, R. B.

FLUID LOGIC

Mechanical Engineering, Vol. 85, No. 6, June 1963, Page 47

Program now underway at the Stanford Research Institute includes study of fluid, usually air, jets to control other larger jets. A new element using tiny spheres has been devised that acts like an electronic NOR logic device. These NOR devices can be readily interconnected to perform all the fundamental logic functions required for digital computing AND, OR, NOT, and memory.

A-032

Ashkenas, H. I. and Bryson, A. E.

DESIGN AND PERFORMANCE OF A SIMPLE INTERFEROMETER FOR WIND-TUNNEL MEASUREMENTS,  
Jour. Aero. Sci., Vol. 18, #2, (1951), p. 82

A-033

Auger, Raymond N.

A NEW "SOLID STATE" PNEUMATIC AMPLIFIER FOR LOGIC SYSTEMS

Automatic Control, Pages 24-28, December, 1962

The "Turbulence amplifier", a new no-moving-parts pneumatic device, is a multiple-input pneumatic amplifier with a proportional range sharp enough to enable the device to be used as a switching element. Among its major assets is the direct interconnectability of the amplifiers with biasing, loading, or impedance matching problems. A second major asset cited is the ability of the units to be built with an almost unlimited number of totally isolated input connections. Turbulence amplifiers are also low-pressure and low power devices, enabling them to obtain their air supply from inexpensive vibrator type pumps or high-volume blowers.

A-034

Auger, Raymond N.

LIQUID LOGIC CIRCUITS ADVANCED IN ZURICH

Automatic Control, Vol. 16, No. 6, Page 43, June, 1962

IBM's Zurich Research Lab has been researching on liquid digital computers for some years. Under the direction of Dr. H. Glaetti, studies have been made for fabricating spool-valve type digital amplifiers and studying the basic phenomena of their operation. Most of these digital circuits are fabricated on a planagraphic type milling machine and a conventional drill press.

A-035

Auger, R. N.

#### PNEUMATICS COMPUTER RESEARCH IN THE USSR

Automatic Control, Page 11, pp. 43-48, December 1960

Information in this article was obtained during two recent visits by Tech. writer, Auger, to the Inst. of Automatics and Telemechanics in Moscow. Virtually all of the components discussed in this article are classified as being in the stage of advanced research. They are structurally simple, however, and quickly manufactured by conventional techniques. The transition from laboratory to industrial application may be rapid.

A-036

Auger, Raymond N.

#### SPOOL VALVE HYDRAULIC DIGITAL COMPUTERS

Automatic Control, Vol. 14, No. 4, Pages 34-36, April, 1961

Most recent announcement of pioneer work in F.D.C. by Dr. H. H. Glaetti of IBM's Zurich Lab described hydraulic operated FDC units containing spool type valves. The devices constructed have been operated at pressures ranging from 1/2 to 150 pci and at frequencies up to 700 cps, with 2000 cps a theoretical maximum.

A-037

Auger, R. N.

#### TURBULENCE AMPLIFIER DESIGN AND APPLICATION

Proceedings of the Fluid Amplification Symposium, Oct., 1962, Vol. I, DOFL, Washington, D. C.

The turbulence amplifier is a pneumatic or hydraulic no-moving-parts fluid amplifier with many unique properties which suit it for use in logic circuits and as a primary sensor of low velocity fluid streams and low energy acoustic waves. The turbulence amplifier produces signal amplification by the disturbance of a laminar flow in a submerged jet.

B-001

Bailey, A. B.

USE OF THE COANDA EFFECT FOR THE DEFLECTION OF JET SHEETS OVER  
SMOOTHLY CURVED SURFACES

Part I, University of Toronto, UTIA Tech. Note #49.

B-002

Bails, W. B., Brown, F. T., Reid, K. N., and Gurski, R. J.

RESEARCH AND DEVELOPMENT OF PNEUMATIC JET RELAY SYSTEM FOR PROPULSION  
SYSTEM CONTROL

Dept. of Mechanical Engr., MIT, Report No. DSR-9159-1 dated 3/31/63

Fluid jet devices with no moving mechanical parts, which can serve as rugged sensing and control elements in advanced air-breathing propulsion systems were the goal of this study. A basic approach for a quasi-static prediction for the dynamic behavior of controlled jets as presented, and implemented by a digital computer. Experimental results of a basic investigation of the impingement of a turbulent jet onto a flat plate are given for a wide variation of Reynolds numbers; and compared with theory, the static and dynamic interactions of jets with receiver ports are discussed, including theoretical and experimental results.

B-003

Baily, D. Z., Barry, F. W., and DeFrate, L. A.

A PORTABLE MACH-ZEHNDER INTERFEROMETER

Meteor Report No. 51, MIT, Cambridge, Mass. (1950)

B-004

Bakke, P.

AN EXPERIMENTAL INVESTIGATION OF THE WALL JET

Journal of Fluid Mechanics, Vol. 2, Pt. 5, Page 467, July, 1957

This paper deals with an experimental investigation of a turbulent low-speed jet of air spreading out radically over a flat smooth plate; a flow which has been discussed by Glauert (1956) in his theory of the wall jet. The aim of the experiments has been to determine the mean velocity distribution and the rate of growth of the jet. It is found within the experimental range and accuracy that the velocity profiles are similar and that the rate of range of velocity and width of the jet can be expressed by simple power laws.

B-005

Barclay, R. G., Warren, R. W., Holmes, A. B.

#### APPLICATION OF FLUID AMPLIFICATION TO ROCKETRY

Diamond Ordnance Fuze Laboratories, Washington, D. C.

The principles of operation of proportional and bistable fluid amplifiers are presented. The application of the amplifiers to reaction controls, pulse duration modulation, and thrust vector control is described.

B-006

Barclay, Ralph G., Bowers, Allen A., Moorhead, John G.

#### FLUID AMPLIFICATION. 10. USE OF THE HYDRAULIC ANALOGY IN THE STUDY OF FLUID-INTERACTION DEVICES

Harry Diamond Lab. ASTIA Report No. TR-1098, also AD-405867

The advantages of using the hydraulic analogy to study compressible gas flow in fluid interaction devices are discussed. The mathematical basis of the analogy is summarized, and limitations in its use are pointed out. Various practical aspects concerning operation of an analogy facility are reviewed.

Four hydraulic-analogy studies are briefly described: subsonic diffuser performance, three-stage closed-system bistable fluid-flow amplifier performance, amplifier, and blocked-output-channel and stream-attachment characteristics in fixed and adjustable models of bistable elements.

Abstracts of 17 references regarding the theory and application of the hydraulic analogy are given.

B-007

Barclay, Ralph G.

#### THE HYDRAULIC ANALOGY

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I (DOFL), Washington, D. C.

The hydraulic analogy is the analogy that exists between two dimensional compressible gas flow and open-channel liquid flow. The main contribution of the hydraulic analogy to the study of fluid amplification is in providing a means of flow visualization.

B-008

Barila, T. G. Lt. Col. Woodward, K. E. Nunn, D. E.,  
Capt. Mon, G. Straub, H. H.

A FLUID-AMPLIFIER ARTIFICIAL HEART PUMP

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I.,  
DOFL, Washington, D. C.

Fluid Amplification has been applied to the powering and control of  
an extra corporeal heart pump. Early evaluation tests suggest its  
performance capabilities and hemalytic characteristics are at least equal  
to those of the better available heart pumps.

B-009

Barlow, G. R., and Lettendre, R. P.

EXPERIMENTAL STUDY OF THE SEPARATION POINT AND SEPARATION BUBBLE

Thesis for Bachelor of Aeronautical Engr., Catholic University of America,  
Washington, D. C., June 1959

B-010

Barnes, N. F. and Bellinger, S. L.

SCHLIEREN AND SHADOWGRAPH EQUIPMENT FOR AIR FLOW ANALYSIS

Jour. Optical Soc. Am. 35 (8): 497 (1945)

B-011

Barry, F. W., Baily, D. Z. and DeFrate, L. A.

A PORTABLE MACH-ZEHNDER INTERFEROMETER

Meteor Report No. 51, MIT, Cambridge, Mass. (1950)

B-012

Bartz, D. R.

AN APPROXIMATE SOLUTION OF COMPRESSIBLE TURBULENT BOUNDARY LAYER  
DEVELOPMENT AND CONVECTIVE HEAT TRANSFER IN CONVERGENT-DIVERGENT  
NOZZLES

ASME Transactions, Vol. 77, Page 1235, Nov. 1955

B-013

Bartz, D. R., Silver, S. and Elliott, D. G.

CALCULATION OF TURBULENT BOUNDARY-LAYER GROWTH AND HEAT TRANSFER IN AXI-SYMMETRIC NOZZLES

J. P. L. Tech. Report #32-387 dated Feb. 15, 1963

B-014

Bauer, P.

PURE FLUID DIGITAL LOGIC WITH A SINGLE SWITCHING ELEMENT

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

The advent of pure fluid amplifiers has introduced the question of economy in the development, design, manufacture, and test of pure fluid circuits and systems. The principles of conventional electronic logic design (such as "NOR" logic) were employed as the basis for the development of one universal digital element to serve a multitude of logic functions, singly and in combinations. Definite and conclusive evidence was desired to prove the objective not only feasible but practical.

B-015

Bellinger, S. L. and Barnes, N. F.

SCHLIEREN AND SHADOWGRAPH EQUIPMENT FOR AIR FLOW ANALYSIS

Jour. Optical Soc. Am. 35 (8): 497 (1945)



B-016

Belsterling, C. A. and Tsui, Ka Cheung

RESEARCH ON THE PERFORMANCE OF PURE FLUID AMPLIFIERS PART I STATIC OR LOW FREQUENCY CASE

Franklin Inst. Laboratories, Interim Report No. I-09761-1 dated Feb., 1963 to August, 1963

The ultimate objective of the research program described in this report is to promote the application of pure fluid devices in systems by describing them in terms familiar to the control systems engineer. The work is intended to define static and dynamic analogies of network parameters, equivalent electrical circuits and transfer functions, and develop analytical and graphical techniques for more convenient system analysis. This report covers a portion of the first phase of the program involving the static case. The work accomplished to date is a significant advance toward the stated objective.

B-017

Berends, T. K. and Tal', A. A. (Moscow)

PNEUMATIC SWITCHING CIRCUITS

Automation and Remote Control, Vol. No. 20, Page 1446, November, 1959

Descriptions are given of apparatus used in constructing pneumatic switching circuits. Methods are demonstrated of realizing by pneumatic means the elementary logical functions and a one-cycle delay function. It is also shown that any finite automation can be constructed by means of pneumoautomata. The circuits are given for several pneumatic devices which implement analog-to-digital conversions.

B-018

Berezovets, G. T., Dimitrier, V. N., Tal', A. A. (Russian)

A NEW TYPE OF PNEUMATIC COMPUTER

Automation and Remote Control, Vol. 22, No. 1, Page 93, August, 1961

This article is concerned with methods for the design of pneumatic analog computers that are based on pneumatic decision amplifiers operating at low pressures (0-100 mm of water). The first part of the article describes methods for performing linear algebraic operations.

B-019

Bialous, A. J., Yerman, A. J.

NEW DEVELOPMENTS IN PRESSURE AND FLOW MEASUREMENT TECHNIQUES

General Electric Report No. 58GL251, Sept. 26, 1958

B-020

Bigliano, R. P.

HERE'S A WAY TO MEASURE PNEUMATIC COMPONENT DYNAMICS

Control Engineering, Pages 72-77, August, 1956

This article describes: (1) comprehensive procedures for testing dynamic characteristics of pneumatic controllers; (2) how to derive and measure the parameters of the transfer functions of pneumatic controllers; and (3) collected data on the dynamics of controllers, transmitters, transmission lines, valve actuators, positioners, and boosters.

B-021

Blackburn, J. F., Reethof, G. and Shearer, J. L.

FLUID POWER CONTROL

Publ. Technology Press, M.I.T. and Wilen, New York, 362 pp. (book), 1960

B-022

Boehler, G. D. Prof.

A SOLUTION OF THE TWO-DIMENSIONAL TURBULENT VISCOUS CURVED JET USING THE IBM-7090 COMPUTER

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I., DOFL, Washington, D. C.

A numerical solution of the two-dimensional curved turbulent and incompressible jet flow, using the IBM-7090 computer, is presented. This solution is a straight-forward extension of the classical straight jet solution. Its only limitation is that it assumes similar velocity profiles.

B-023

Boothe, W. A., Shinn, J. N. Dr.

A SUGGESTED SYSTEM OF SCHEMATIC SYMBOLS FOR FLUID AMPLIFIER CIRCUITRY

Proceedings of the Fluid Amplification Symposium, October, 1962,  
Vol. 1, DOFL, Washington, D. C.

This paper proposes a system of short-hand symbols that effectively differentiates between analog and digital devices, beam deflector and vortex amplifiers and passive versus active types of valves. A means of designating the memory and no-memory digital amplifier is also provided. On this simple base, it is possible to build symbols representing the more sophisticated logic and control components. Examples given include an operational amplifier, simple flip-flop, counter, half-adder (or exclusive OR), AND, OR and NOT elements.

B-024

Boothe, W. A.

PERFORMANCE EVALUATION OF A HIGH PRESSURE-RECOVERY BISTABLE FLUID AMPLIFIER

ASME Symposium Report on Fluid Jet Control Devices, Nov., 28, 1962

Data taken on the same valve under several control modes and operating with both a compressible fluid (air) and an incompressible fluid (water) show a strong similarity in output characteristics. It is in the input characteristics that considerable differences are felt as the type of fluid and mode of control are changed.

Except for extremely small, low pressure elements, Reynolds number effects have yet to prove strong, and preliminary results indicate good correlation of data over step-down ranges of at least 4:1.

B-025

Borques, C., and Newman, B. G.

REATTACHMENT OF A TWO-DIMENSIONAL INCOMPRESSIBLE JET TO AN ADJACENT FLAT PLATE

Aeronautical Quarterly, Vol. XI, August, 1960

As part of a general investigation into Coanda effect, a study has been made of the reattachment of a two-dimensional incompressible, turbulent jet to an adjacent, inclined flat plate. The jet separates from the boundaries at the slot lips and reattaches to the plate downstream, a phenomenon which is associated with the lowering of the pressure between the jet and the plate accompanying the intrainment of fluid there.

B-026

Bourque, C.

DEVIATION D'UN JET TURBULENT INCOMPRESSIBLE PAR UN VOLET INCLINE  
"EFFECT COANDA"

Master's Thesis, L'universite Laval, August 1959

B-027

Bowers, Allen A., Barclay, Ralph G., Moorhead, John G.

FLUID AMPLIFICATION 10. USE OF THE HYDRAULIC ANALOGY IN THE STUDY OF  
FLUID-INTERACTION DEVICES

Harry Diamond Lab. ASTIA Report No. TR-1098, also AD-40587

See author R. G. Barclay

B-028

Bowles, R. E. (Dr.), Brown, F. T.

FLUID SYSTEMS WITH NO MOVING PARTS

Paper presented September 1963 I.F.A.C. Mtg. at Zurich, Switzerland

Three-dimensional fluid amplifiers, with no moving mechanical parts, using feedback passages, existed in the 19th century. Fluid Diodes were built in the 1920's and vortex amplifiers in the early 1950's. The field was relatively dormant until late 1950, when independent work in the United States and Russia sparked new interest and invention.

B-029

Bowles, R. E. (Dr.)

MINIATURIZED FLUID CONTROL SUBSYSTEMS MAKE MOVING MECHANICAL PARTS PASSE

SAE Trans. October 1961, Page 91

Miniaturized fluid control subsystems are being built from digital and logic components having no moving mechanical parts. New design and production techniques will provide these components and systems for research and development programs in pure fluid systems.

B-030

Bowles, R. E. (Dr.), Colston, J. R.

OPTIFORM, OPTICAL MACHINING OF PURE FLUID SYSTEMS IN PLASTICS

Proceedings of the Fluid Amplification Symposium, October, 1962,  
Vol. 1, DOFL, Washington, D. C.

Optiform is a low-cost, fast production technique for machining constant-depth pure fluid systems in plastic. With optiform and a file of silhouettes of components of known performance characteristics, one can assemble a pure fluid control system at the drawing board with high probability that the first of the resulting low cost short lead-time production models will function properly.

B-031

Bowles, R. E. (Dr.)

PURE FLUID SYSTEMS

ASME Symposium on Fluid Jet Control Devices, Winter Annual Meeting,  
New York, 1962

B-032

Bowles, R. E. (Dr.)

STATE OF THE ART OF PURE FLUID SYSTEMS

ASME Symposium Report dated November 28, 1962 (Fluid Jet Control Devices)

Three basic amplification techniques furnish a foundation for "active" components in this field. Horton's Stream Interaction Amplifiers use the momentum of fluid control jets to direct the delivery of a fluid power jet to a system of receiving apertures. The Boundary Layer Control Amplifiers (Bowles and Warren) use the pressure distribution in the interaction region between the power jet and the side walls to direct the power jet. The vortex amplifiers (Bowles and Hertton) provide very high gain using conservation of angular momentum.

B-033

Boyer, L. J.

PRELIMINARY INVESTIGATION AND EVALUATION OF THE COANDA EFFECT

Technical Intelligence Div., AMC, Wright Field, Dayton, Ohio, Tech. Rept.  
No. F-TR-2207-ND(1948) ASTIA ATI No. 26895

B-034

Braithwaite, R. C. and Wilcox, K.

MECHANICAL RELAY OF THE FLUID JET TYPE

U. S. Patent No. 2,408,603

B-035

Bown, E. C.

A PNEUMATIC-HYDRAULIC APPROACH TO POINT-TO-POINT POSITIONING

North East Electronics Research and Engineering Meeting, Boston,  
November 1960 (Institute of Radio Engineers)

B-036

Brown, F. T. Prof.

A COMBINED ANALYTICAL AND EXPERIMENTAL APPROACH TO THE DEVELOPMENT OF  
FLUID-JET AMPLIFIERS

ASME Paper 62-WA-154 July 30, 1962

An approach to the development of "pressure-controlled" fluid-jet relays and amplifiers is proposed. The technique, based on experiments of a jet attaching to a flat wall combines theoretical reasoning, experimental data, and graphical source-load matching. Single control and symmetrical double-control amplifiers of a particular "knife-edge" design are used in the illustrations of the approach, typical data are given. Static and dynamic stability of the jet is emphasized including the criteria for oscillators.

B-037

Brown, F. T., Bowles, R. E.

FLUID SYSTEMS WITH NO MOVING PARTS

Paper presented at I.F.A.C. Meeting, September 1963 at Zurich, Switzerland

See author Bowles, R. E.

B-038

Brown, F. T.

#### HYDRAULIC AND PNEUMATIC TRANSMISSION LINES

M.I.T. Dept. of Mech. Eng. Course #2.78S, Summer 1960, Pages 1-32

In the design of fluid power control systems, one often has to contend with the wave motion in the fluid lines. These wave motions may produce important delays, or disastrous oscillations or pressure pulses. There is also now a beginning interest in the utilization of wave motion phenomena in fluid lines to transmit information - as the electromagnetic transmission line has done for decades.

The purpose of this paper is merely to point out, for the person confronted with a problem in pneumatic or hydraulic pulse transmission, a few of the solution techniques that are applicable. Many of the important details and specific applications are absent, especially when they are nearly given in easily available references.

B-039

Brown, F. T.

#### ON THE INHERENT LIMITATIONS IN FLUID JET MODULATORS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I., DOFL, Washington, D. C.

The manner in which wave motion, energy dissipation, and gross jet turbulence produce inherent limitations in fluid jet modulators is qualitatively discussed. Topics include surge impedance matching at input and load parts, the possibility of nearly infinite pressure and power gains of "Momentum-Controlled" and "Pressure-Controlled" jet amplifiers, and the effect of nozzle design on jet noise with implications on the signal-to-noise ratio and other operating conditions.

B-040

Brown, F. T.

#### PNEUMATIC PULSE TRANSMISSION WITH BI-STABLE JET RELAY RECEPTION AND AMPLIFICATION

Sc.D. Thesis, M.I.T., Dept. of M.E., May, 1962

A system is developed in which the command position of an output shaft is encoded into a pulse-position-modulated signal, converted to pneumatic pulses, transmitted along a line received, amplified and integrated by a two-stage bistable jet relay without moving parts, and demodulated by the push-pull piston-cylinder load, which assumes the commanded position. Modulation periods are of the order of five milliseconds. Theory is developed for the dispersion of transients in fluid lines.

B-041

Brown, F. T., Reid, K. N., Gurski, R. J., and Bails, W. B.

RESEARCH AND DEVELOPMENT OF PNEUMATIC JET RELAY SYSTEM FOR PROPULSION  
SYSTEM CONTROL

Dept. of Mechanical Engr., MIT, Report No. DSR-9159-1 dated 3/31/63

See author Bails, W. B.

B-042

Brown, F. T.

THE TRANSIENT RESPONSE OF FLUID LINES

Transactions of the A.S.M.E. (Journal of Basic Engineering) Page 547,  
December, 1962

Functional operators are derived for the propagation factor and characteristic impedance for small amplitude waves in rigid uniform fluid transmission lines when the effects of varying velocity profile and heat transfer are included. The special case of sinusoidal excitation yields the identical result given by Iberall. The results, however, are used particularly to determine the impulse and step responses of line, which clearly demonstrate the observed dispersion of fast transients.

B-043

Bryce, Barbara Ann

FLUID JET RELAY DEVICES: A PARTIALLY ANNOTATED BIBLIOGRAPHY

Autometics, Downey, Calif., Rept. No. EM-1162-114, AD-276 419,  
80 p., May 21, 1962

The devices and related theory, as encompassed within this survey, are fluid control devices which contain no moving parts and are referred to variably as fluid amplifiers, pure fluid systems, and fluid binary logic elements. The theoretical aspects include the laminar boundary layer, fluid mechanics, two-dimensional flow of gases, and the Coanda effect. For related material, see Autometics Report EM-1162-113, Secondary Fluid Injection for Thrust Vector Control; A Partially Annotated Bibliography, dated May 21, 1962. The four sections of the report are: Section A - Fluid Jet Relay Devices: (1) Theory and Analysis, (2) Experiments and Methods, and (3) Types of Devices in Research and Development; Section B consists of Tangent (or closely related) References. The 280 references are alphabetized by title within each of the four sections. Two indexes, an author and a company and periodical source, conclude this report.



B-044

Bryson, A. E. and Ashkenas, H. I.

DESIGN AND PERFORMANCE OF A SIMPLE INTERFEROMETER FOR WIND-TUNNEL MEASUREMENTS

Jour. Aero. Sci., Vol. 18, #2, (1951), p. 82

B-045

Byrd, J. L. and Williams, James G.

STATIC PRESSURE DISTRIBUTION ALONG AN INCLINED, SETBACK PLATE WITH ATTACHED JET USING THE HYDRAULIC ANALOGY

U. S. Army Missile Command Redstone Arsenal, Alabama. RG-TR-63-15.  
Available from Defense Document Center, Cameron Station, Alexandria, Va. 22314

C-001

Caille, C.

RIGHT ANGLED EMERGENCE OF AIR FROM A DUCT

Engineering Digest, August 1955, pp. 42-44, from Sulzer Technical Review, Winterthur, Switzerland, Vol. 38, No. 1 (1956)

C-002

Campagnuolo, Carl J.

A THREE-STAGE DIGITAL AMPLIFIER

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I., DOFL, Washington, D. C.

This paper describes digital pneumatic elements, cascaded so as to obtain a high power output which can be controlled by means of a stream containing  $10^3$  of the output flow; a system consisting of three units in a cascade is discussed.

C-003

Cargill, N. A.

U. S. Patent No. 3,071,154

This invention provides electrical means for controlling a fluid amplifier without the need for an intermediate transducer. Has only one fluid input stream called the power stream. Provides means responsive to small power electrical signals for producing larger power fluid signals. Provides multistable switches responsive to electrical signals for producing fluid output signals.

C-004

Chang, Paul K.

LAMINAR SEPARATION OF FLOW AROUND SYMMETRICAL STRUTS AT ZERO ANGLE OF ATTACK

Journal of the Franklin Institute, Vol. 270, No. 5, November 1960.

C-005

Chang, Paul K.

SURVEY ON COANDA FLOW

Proc. of the Fluid Amplification Symposium, Vol. I., Oct. 2-4, 1962,  
Pages 95-108

A survey of 31 available references of analyses and experiments was made on Coanda flow which clings to a curved or deflected surface and increases mass rate-of-flow. This survey may be useful to better understand the mechanics of this type of flow and for its practical use of fluid amplification.

C-006

Chapin, D. W.

A PNEUMATIC COMPUTER FOR PROCESS CONTROL, PART I

ISA Journal, Vol. 8, No. 9, Page 38-43, September 1961

Ai Research long a standout maker of air-operated devices for military and commercial aeronautics, has developed the "ADAC" (Ai Research Pneumatic Analog Computer). Outstanding feature: No signal conversion necessary, its inputs and outputs are the standard 3 to 15 psi signal of commercial pneumatic transmitters, controllers and valve actuators. This article describes the eight basic modules which comprise this computer.

C-007

Chapin, D. W.

A PNEUMATIC COMPUTER FOR PROCESS CONTROL PART II

ISA Journal, Vol. 8, No. 10, Page 53, October 1961

Part I described the eight basic modules which comprise the Ai Research Pneumatic Analog Computer--"AIRPAC." The second part explains how these modules are combined to form almost any required analog computer and where and when to apply such computers to process control.

C-008

Chapman, D. R., Kuehn, D. M., and Larson, H. K.

INVESTIGATION OF SEPARATED FLOWS IN SUPERSONIC AND SUBSONIC STREAMS  
WITH EMPHASIS ON THE EFFECT OF TRANSITION

Tech. Note Nat'l Adv. Comm. Aero, Washington, No. 3869, 1957

C-009

Chow, W. L., Korst, H. H., Mueller, T. J.

ON THE SEPARATION REATTACHMENT AND REDEVELOPMENT OF INCOMPRESSIBLE  
TURBULENT SHEAR FLOW

Journal of Basic Engineering, Paper No. 63, March, 1963

An experimental and theoretical investigation is presented which describes the character of the mean motion and the structure of turbulence for the separation: reattachment and redevelopment of the incompressible turbulent shear flow downstream of a single step-type roughness element.

C-010

Coanda, H.

PROCEDE ET DISPOSITIF POUR FAIRE DEVIER, UNE VEINE FLUIDE PENETRANT  
AUTRE FLUIDS

Patent No. 788,140 (France) 217: 1934

C-011

Coanda, H. and Metral, A. R.

THE COANDA EFFECT

Final Report USAF Contract AF61(514)1409 (Contract between A.R.D.C.  
Brussels and SFERI-Coanda, Clichy, France)

C-012

Cochran, W. L. and Van Tilburg, R. W.

FABRICATION OF FLUID AMPLIFIERS BY OPTICAL FABRICATION TECHNIQUES

Corning Glass Co. First 9 Mo Progress Report ending Dec. 31, 1962 for  
Harry Diamond Lab Contract No. DA-49-186-ORD-1076

Detailed discussion of the results of a program designed to determine the feasibility of producing pure fluid circuits in Fotoform glass using optical fabrication techniques is given. It was specifically desired to determine effects of Fotoform process variations on amplifier performance and to establish the suitability of the process and to the rapid modification redesign, and re-evaluation of fluid amplifier elements and circuits.

C-013

Cohen, H. and Tu, Yih-O

A THEORETICAL MODEL FOR SEPARATION IN THE FLUID JET AMPLIFIER

IBM - Journal of Research and Dev., Vol. 7, No. 4, October 1963

A theoretical study, based on the re-entrant jet model, is made of the growth of the separation region in the fluid jet amplifier. The flow is taken to be inviscid but dissipation of momentum is obtained by means of the re-entrant jet. The effect of control port pressure and wall angle on the size of the separation region is calculated. Several other versions of the model are suggested.

C-014

Coles, D. E.

THE TURBULENT BOUNDARY LAYER IN A COMPRESSIBLE FLUID

Rand Corporation Report #P-2417 dated August 22, 1961

C-015

Colston, J. R. (Bowles Engr. Corp.)

A PNEUMATIC PURE FLUID SPEED CONTROL FOR A 500 KW STEAM TURBINE GENERATOR

Bowles Engr. Report (Contract NONR-4033 (00) dated September 1963

A pneumatic pure fluid speed control was designed and constructed for a 500 KW steam turbine generator. Its performance was demonstrated in a laboratory bench test on a scaled system. The unit met the specification for 1/2% speed control for a 10% load change. This report covers the selection of a suitable system, a description of the performance of each component, and a summary of the test results.

C-016

Colston, J. R., Bowles, R. E.

OPTIFORM, OPTICAL MACHINING OF PURE FLUID SYSTEMS IN PLASTICS

Proceedings of the Fluid Ampl. Symposium, October, 1962, Vol. I., DOFL, Washington, D. C.

See author Bowles, R. E.

C-017

Comparin, Dr. R. A., Mitchell, Dr. A. E., Mueller, Dr. H. R.,  
Glaettli, H. M.

#### ON THE LIMITATIONS AND SPECIAL EFFECTS IN FLUID JET AMPLIFIERS

ASME Symposium Report on Fluid Jet Control Devices dated November 28, 1962

There is a minimum Reynolds number below which reattachment of the jet to a boundary wall does not take place and that this number is in some way related to the shear layer at the edge of the jet and is very dependent on the geometrical shape of the element. The minimum size of an element for all fluids, except the more viscous oils, is below that which can be considered a reasonable manufacturing size. Elements should be made as short as possible, so that the response time of the jet can be reduced.

C-018

Comparin, R. A.

#### SOME EFFECTS OF GEOMETRY IN A FLUID AMPLIFIER

IBM Research Note N Z-4, Zurich Research Laboratory

Several theories have been developed for the separation and reattachment of jets to inclined and parallel walls. A bibliography and summary of these theories is given. These theories are limited to the case of  $\alpha > 730^\circ$  and Reynolds Numbers greater than 1500. The theories have been developed only for single sided elements so they cannot be applied directly to the configurations encountered in bistable fluid amplifiers.

C-019

Cooper, R. E. and Sherrill, W. M.

#### SOME CURRENT REQUIREMENTS OF MILITARY CONTROL SYSTEMS

Proceedings of the Fluid Amplification Symposium, October, 1962,  
Vol. II

Data are presented from a 1961 cross-section survey of 108 military control systems. The survey was conducted by personal interviews of 37 control manufacturers and users. The survey purpose was to determine fluid amplifier device applicability to military control systems. Control system data are presented according to type, function, cost, response time, and angular precision.

C-020

Crabtree, L. F.

EFFECTS OF LEADING EDGE SEPARATION ON THIN WINGS IN TWO-DIMENSIONAL  
INCOMPRESSIBLE FLOW

J. Aero, Sci., Vol. 24, p. 597, 1957

C-021

Crabtree, L. F.

THE FORMATION OF REGIONS OF SEPARATED FLOW ON WING-SURFACES

Aero-Res. Council. R. and M 3122, 1959

C-022

Crane, L. J.

THE LAMINAR AND TURBULENT MIXING OF JETS OF COMPRESSIBLE FLUID

Journal of Fluid Mechanics, Vol. 3, Part I, October, 1957, Page 81

This paper presents the application of the methods developed to the mixing of two parallel streams for both laminar and turbulent flows. The effects of both high velocity and large temperature difference are treated together.

C-023

Crane, L. J.

LAMINAR AND TURBULENT MIXING OF JETS OF COMPRESSIBLE FLUIDS

Journal of Fluid Mechanics, 1957

C-024

Croccon, L. and Lees, L.

A MIXING THEORY FOR THE INTERACTION BETWEEN DISSIPATIVE FLOWS AND NEARLY  
ISENTROPIC STREAMS

Journal of the Aeronautical Sciences, Vol. 19, 1952-Pages 649-676

C-025

Curtiss, H. A. and Lequornik, D. J.

RESEARCH STUDIES IN PROPORTIONAL FLUID STATE CONTROL COMPONENTS

Giannini Controls Corp. Report ARD-TR-013-01 dated September 1963

C-026

Curtiss, H. A. and Lequornik, D. J.

RESEARCH STUDIES IN PROPORTIONAL FLUID STATE CONTROL COMPONENTS

Final Report Contract, DA 36-034-ORD-3722RD, Redstone Arsenal,  
Ala. (Giannini Controls Corp.)



D-001

Dai, Y. B., Albertson, M. L., Jensen, R. A. and Rouse, H.

DIFFUSION OF SUBMERGED JETS

Proceedings ASCE, Vol. 74, Part 2, Page 1571

D-002

DeFrate, L. A., Barry, F. W. and Baily, D. Z.

A PORTABLE MACH-ZEHNDER INTERFEROMETER

Meteor Report No. 51, MIT, Cambridge, Mass. (1950)

D-003

Denavit, J. and Hartenberg, R. S.

THE FABULOUS AIR COMPRESSOR

Machine Design, Page 168, July 21, 1960

In generations past mining engineers used an air compressor that had no moving hardware and yet produced air at 120 psi or so for the compressed air tools and appurtenances of mines. Though long since superseded, this compressor was a unique contribution by civil engineers to the evaluation of pneumatic power in industry.

D-004

Dexter, E. M.

A TECHNIQUE FOR MATCHING PURE FLUID COMPONENTS APPLIED TO THE DESIGN OF A SHIFT REGISTER

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I., DOFL, Washington, D. C.

An approximate scheme which has proven useful in evaluating the matching possibilities of units, quality, control, and circuit testing is described. The first assumption was that a considerable safety factor is desired with digital elements, i.e., it is desired to have somewhat more pressure available to flip a unit than required. Secondly, allowance must be provided for the differences between elements to be encountered in practice.

D-005

Dexter, E. M.

AN ANALOG PURE FLUID AMPLIFIER

ASME Symposium Report (Fluid Jet Control Devices) dated Nov. 28, 1962

The calculations given in this report provide a basis for a model investigation. They show that the receivers for a general purpose amplifier should be located somewhere between 6 and 9 power nozzle diameters downstream. For staging it is desirable to have receivers and control nozzles of the same area. The model investigation provided information on noise attenuation, the size and location of the vent areas, and the desirability of providing a cross vent under the power jet.

D-006

Dexter, E. M.

NO MOVING PARTS - FEATURE OF NEW VALVES

S.A.E. Journal, Page 102, September, 1961

Major changes, in the form of controls without moving parts, are beginning to take place in the fluid power industry. Such devices, by their inherent simplicity, are desirable for getting higher reliability. A good example is the no moving part check valve, and the vortex valve.

D-007

Dexter, E. M.

VORTEX VALVE DEVELOPMENT

G. E. L. Report, pages 1 - 7, 13 Figures, April 17, 1961

The development of the vortex valve is discussed in great detail and summarizes that the important aspect of this development is not in its specific execution but the general method being attempted to produce a control without moving parts.

D-008

Diamond Ordnance Fuze Lab.

PROCEEDINGS OF THE FLUID AMPLIFICATION SYMPOSIUM - VOLUME I

Proceedings of the Symposium held October 2, 3, and 4, 1962. AD-297 935

Volume I includes all unclassified presentations. Volume II includes all classified presentations which were given during the last half day of the symposium.

In addition to providing the first formal opportunity for the exchange of information regarding fluid amplification, an explicit objective of the symposium was to bring together the various persons interested in this new and yet unorganized field.

No record was made of the welcoming addresses delivered by Lt. Col. R. W. McEvoy, Commanding Officer, and B. M. Horton, Tech. Director, D.O.F. Lab., and their remarks are consequently not included. Their great interest in the field are perhaps sufficiently well known to make this omission excusable.

No attempt was made to edit the papers as presented at the D.O.F. Lab; they were merely assembled and printed in the same order in which they were presented at the symposium.

D-009

Diefenderer, V. C.

PNEUMATIC-POSITIONING-STEP OR INFINITE CONTROL

Hydraulics and Pneumatics, Page 59, June, 1961

Pneumatic-positioners are either multi-positioning or infinity-positioning. The multi-position cylinder allows two or more pre-determined stopping positions during its stroke. The infinite positioner allows stepless, controllable, linear actuation. These versatile devices simplify mechanical design by eliminating intricate cams and linkages.

D-010

Dimitrier, V. N., Berezovets, G. T., Tal', A. A. (Russian)

A NEW TYPE OF PNEUMATIC COMPUTER

Automation and Remote Control, Vol. 22, No. 1, Page 93, August, 1961

See author Berezovets, G. T.

D-011

Dockery, R. J., and Katz, S.

GENERALIZED PERFORMANCE CHARACTERISTICS OF PROPORTIONAL AND BISTABLE  
FLUID AMPLIFIERS

Harry Diamond Lab Report R-RCA-63-13 dated April 17, 1963

The generalized performance characteristics are examined in detail for both proportional and bistable (digital) fluid amplifiers with no moving parts. An approach leading to the solution of fluid systems design problems is given. Equations describing curves are drawn showing performance trends with several variables manipulated. Experimental curves are presented confirming the theoretical approach. A typical proportional unit, with principle dimensions, is shown with its characteristic curves.

D-012

Donaldson, C. and Snedeker, R. S.

EXPERIMENTAL INVESTIGATION OF THE STRUCTURES OF VORTICES IN SIMPLE  
CYLINDRICAL VORTEX CHAMBERS

NASA Report N63-12987 dated December, 1962

An experimental study of the character of vortices in simple cylindrical vortex chambers completely open at one end is presented. Special attention is given to the problem of the transition from one-celled to two-celled vortex structure.

D-013

Dosanjh, D. S. and Sheeran, W. J. (Syracuse University)

EXPERIMENTS WITH TWO-DIMENSIONAL, TRANSVERSELY IMPINGING JETS

Reprint from AIAA Journal, February, 1963, Vol. I, No. 2

Experiments on the interaction of transversely impinging two-dimensional jet flows were performed in which a low pressure control jet flow interacted with a relatively high pressure power jet flow. The ratio of the control jet to the power jet supply chamber gauge stagnation pressure was adjusted at 0, 10 and 15%. Shadowgraphs of the power jet alone, as well as the corresponding interacting jet flows, were recorded to establish the nature of and changes in the shock structure.

D-014

Dosanjh, D. S. and Weeks, T. M.

INTERACTION BETWEEN AN ADVANCING SHOCK WAVE AND OPPOSING JET FLOW

AIAA Journal, Vol. 1, No. 7, July, 1963

The interaction between a plane shock wave advancing in a shock tube and an opposing axisymmetric jet flow was recorded experimentally and analyzed. Shadow graphs, schlieren, and interferometric observations revealed that the shape of the shock distortions (bulges) caused by the jet flow closely resembled that of the local jet mean velocity distribution.

D-015

Dosanjh, D. S. and Sheeran, W. J. (Syracuse University)

INTERACTING JET FLOW INVESTIGATIONS PART I FURTHER EXPERIMENTS WITH TWO-DIMENSIONAL UNDEREXPANDED, TRANSVERSELY IMPINGING JET FLOWS

Syracuse University Research Institute - Dept. of ME - Report No. ME1058-63091 (February 1963)

Experiments were performed with transversely impinging, two-dimensional underexpanded jet flows. The previously observed radical changes in shock structure and recovery stagnation pressure distribution in a highly underexpanded jet flow due to the transverse impingement of a relatively low pressure jet flow were investigated further. From pitot pressure tranverses shadowgraphs, and schlieren photographs, it was determined that while an earlier proposed interaction model can be used to explain the pitot pressure distributions, certain new effects suggest a possible modification.

D-016

Dosanjh, D. S., Sheeran, W. J.

INTERACTION OF TRANSVERSELY IMPINGING JETS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

Experiments on the interaction of transversely impinging jet flows were performed in which a low pressure control jet flow interacted with a relatively high pressure power jet flow.

E-001

Eck, B.

TECHNISCHE STROMUNGSLEHRE

Second Edition, Springer Verlag, Berlin, p. 193, 1944

E-002

Ehlers, F. E.

THE INFLUENCE OF VISCOSITY ON THE FLOW OF GASES THROUGH LONG TUBES  
AND SLOTS

(Boeing Scientific Research Lab) NASA Rept. N63-16928, May, 1962

The isothermal and the adiabatic flow of a viscous gas through a long straight channel were analyzed under the assumption of constant wall temperature, a Prandtl number of unity, and a parabolic boundary-layer velocity profile. Two regimes of flow were found. For inlet mach numbers below a critical value, the boundary layer builds up and eventually fills the channel. The ratio of the length of this inlet region to the Reynolds number based on inlet conditions was found as a function of the inlet mach number.

E-003

Eklund, Karl

STABILIZING ON-OFF PNEUMATIC CONTROL SYSTEMS

Control Engineering, Page 134, October, 1960

On-off elements and air as a working fluid, are by themselves not unusual. But they are rarely found in combination in high performance control systems. On-off pneumatic control systems do, however, appear to offer the advantages of good operational performance and convenient mechanical design--in spite of the difficulty of analyzing their non-linear behavior. To prove the feasibility of on-off pneumatic control, a study was made for the Stratos Div, Fairchild Aircraft and Engine Corp. of the control system for a turbojet engine variable area exhaust nozzle. The system analysis presented concludes that these highly non-linear control systems can be made stable and suitably damped by using a two-deadband control valve and rate feedback.

E-004

Elliott, D. G., Bartz, D. R. and Silver, S.

CALCULATION OF TURBULENT BOUNDARY-LAYER GROWTH AND HEAT TRANSFER IN  
AXI-SYMMETRIC NOZZLES

J. P. L. Tech. Report #32-387 dated Feb. 15, 1963

E-005

Ezekiel, F. D.

DYNAMIC REPRESENTATION OF LOSSLESS DISTRIBUTED SYSTEMS

Control Engineering, May, 1958

A distributed-parameter system is one in which variations in space occur simultaneously with transient variations. Whenever the variations with respect to space are as large as the variations with respect to time, that is whenever the physical length approaches the characteristic wave length, a lumped-parameter approximation of the dynamics is inaccurate and practical differential equations must be used. From the partial differential equations for a hydraulic line, this data file develops a simple way to represent transient behavior with time delay operations.

E-006

Ezekiel, F. D., Greenwood, R. J.

HYDRAULICS HALF-ADD BINARY NUMBERS

Control Engineering, Page 145, February, 1961

Lab work at MIT has developed the form of a fluid logic element that can be used for adding binary numbers. The elements have no moving parts, operating on the principle of momentum exchange between two fluids as they impinge on each other. Models were built of plexiglass and hydraulic fluid was used.

F-001

Foa, J. V. and Markstein, G. H.

THEORETICAL ANALYSIS OF FLOW PHENOMENA IN A PULSE JET

Cornell Aeronautical Lab Proj. SQUID, Semi-Annual Prog. Rpt., Jet Propulsion Engines, 1952

F-002

Forbister, J. G., and Frauenberger, J. H.

THE AXIAL DECAY AND RADIAL SPREADING OF A SUPERSONIC JET EXHAUSTING INTO AIR AT REST

Aeronautical Quarterly, Vol. XII, Page 131

F-003

Forstall, W. Jr. and Shapiro, A.

MOMENTUM AND MASS TRANSFER IN COAXIAL GAS JETS

Journal of Applied Mechanics, Dec. 1950, Page 399

F-004

Forthmann, E.

UBER TURBULENTE STRAHLAUS-BREITUNG

Ing. Arch. Vol. 5, 1934, Page 42,  
Also: NACA TM 789 (1936)

F-005

Fox, H. L.

A COMPARISON OF THE RELIABILITY OF ELECTRONIC COMPONENTS AND PURE FLUID AMPLIFIERS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

Current achievements in attaining high reliability for components are compared to the predicted reliability of pure fluid amplifiers. Figures for electronic components are presented for various environmental regimes which may be encountered in industrial, field, and aerospace applications.



F-006

Fox, H. L. Wood, O. L.

A SURVEY OF FLUID DEVICES FOR AUTOMATIC CONTROL SYSTEMS

Paper presented at 6th Region I.E.E.E. Technical Conference, April 26, 1963  
(Sperry Utah Co.)

From the information available, it is obvious that proportional fluid amplifiers are easier to work with than are digital devices. The biggest problem is the interconnection of devices in logical arrays. It is predicted that in late 1963, some company will announce the successful solution of the design and interconnection of fluid logic elements in such a manner that operational speeds of fluid logical arrays in excess of 1,000 cycles per sec. will be demonstrated.

F-007

Frauenberger, J. H. and Forbister, J. G.

THE AXIAL DECAY AND RADIAL SPREADING OF A SUPERSONIC JET EXHAUSTING  
INTO AIR AT REST

Aeronautical Quarterly, Vol. XII, Page 131

F-008

Frede, W. (German)

PNEUMATIC COMPUTING ELEMENTS FOR AUTOMATIC CONTROLS

Engineers Digest, Vol. 17, No. 11, Pages 480-482, November, 1956

Describes the basic features of pneumatic computing elements capable of performing various arithmetical operations in control circuits. They can also be developed to produce exponential and other functions required in practice.

G-001

Gates, M. F.

STATIC LIFT-CHARACTERISTICS OF JET SLOTS - A CLARIFYING STUDY OF THE  
EXTERNAL EJECTOR

Advanced Research Division of Hiller Aircraft Corporation, Rept.  
No. ARD-213 (1958). Final Report Contract No. Nonr-2428(00)

G-002

Gibson, J. E. and Tutuer, F. B.

CONTROL SYSTEM COMPONENTS

McGraw Hill, 1958

G-003

Glaettli, H. H., Mitchell, A. E., Mueller, H. R.

FLUID LOGIC DEVICES AND CIRCUITS

IBM Research Paper - RZ-99 - September 20, 1962, Zurich Research Lab,  
Ruschlikon-Zurich (Transl. Society of Inst. Technology, Feb. 26, 1963),  
Switzerland

See Mitchell, A. E.

G-004

Glaettli, H. H.

HYDRAULIC LOGIC, WHAT'S ITS POTENTIAL

Control Engineering, Vol. 8, No. 5, Page 83, May, 1961

Signal-level hydraulic switching devices offer a new tool from which to build logic networks. Speed is about the same as that of conventional relays, while a simple valves' logic power lies midway between that of transistors and relays. Although hydrodynamic and inertial effects cause problems, practical devices have been built and more are proposed. The future looks bright since the use of plastic molding techniques to form multielement units promises lower production costs and higher switching speeds.

G-005

Glaettli, H. M., Comparin, Dr. R. A., Mitchell, Dr. A. E.,  
Mueller, Dr. H. R.

ON THE LIMITATIONS AND SPECIAL EFFECTS IN FLUID JET AMPLIFIERS

ASME Symposium Report on Fluid Jet Control Devices, November 28, 1962

See author, Comparin, R. A. (Dr.)

G-006

Glaettli, H. H.

REMARKS ON THE PURE FLUID AMPLIFIER

IBM - Research Note NZ-2, Zurich Research Laboratory

Points out the basic fluid-dynamics phenomena allowing amplification without moving solid parts or deforming elastic elements. Explanation given is somewhat different from that given by the inventors, Dr. R. E. Bowles, et. al, (DOFL). Their way has the advantage of being a good starting point without requiring special knowledge in hydrodynamics.

G-007

Glauert, M. B.

THE WALL JET

Journal of Fluid Mechanics, Vol. I, Page 625, 1956

This paper considers the flow due to a jet spreading out over a plane surface, either radically or in two dimensions. Solutions of the boundary layer equations are sought, according to which the form of the velocity distribution across the jet does not vary along its length. For laminar flow, such a similarity solution is obtained explicitly. For turbulent flow, an eddy viscosity is introduced, and it is eventually seen that complete similarity is not attainable, but that confident predictions can, nevertheless, be made about the nature of the velocity distribution and the rate of growth of the wall jet.

G-008

Glick, H. H.

MODIFIED CORCCO LEES MIXING THEORY FOR SUPERSONIC SEPARATED AND REATTACHING FLOWS

Guggenheim Aeronautical Lab., California Institute of Technology,  
Hypersonic Research Project Memo. No. 53, May, 1960

G-009

Gomf, G. E.

SUPERSONIC NOZZLE DESIGN FOR VARIOUS FLUIDS

Thesis in Aeronautical Engineering, California Institute of Technology, Pasadena, California, 1949

G-010

Görtler, H.

BERECHNUNG VON AUFGABEN DER FREIEN TURBULENZ AUF GRUND EINES NEUEN NÄHERUNGSANSATZES

Zeitschrift für angewandte Mathematik und Mechanik, Vol. 22, p. 244, 1942

G-011

Goto, J. M., Peperone, S. J., Katz, S.

FLUID AMPLIFICATION-GAIN ANALYSIS OF THE PROPORTIONAL FLUID AMPLIFIER

ASTIA Report AD-296513, October, 1962 (DOFL Report No. TR-1073)

A theoretical analysis of signal gain using principles of fluid stream interaction is presented. This analysis is applied to predict pressure flow and power gains of a fluid amplifier and to determine optimum operating conditions and geometry. Comparison of theory and measurements show agreement within the experimental error.

G-012

Granqvist, C. E.

GYROSCOPE DEVICE WITH VIBRATING GAS PARTICLES OR PARTICLES OF ANOTHER SOUND TRANSFERRING MEDIUM

U. S. Patent Docket 2,999,389 (Sweden, Ser. No. 798,037 dated March 9, 1959)

A gyroscopic device comprising a sound conductor containing a fluid sound conducting medium means for generating a sustained, standing, longitudinal oscillation within said conductor, and means on opposite sides of a nodal point of said oscillation for measuring changes in pressure of said nodal point when said conductor is displaced in a direction perpendicular to said longitudinal oscillation.

G-013

Greber, I.

BUBBLE PRESSURES UNDER RE-ATTACHING LAMINAR JETS AND BOUNDARY LAYERS

ASME Symposium Report on Fluid Jet Control Devices, November 28, 1962

Pressures in the separated region under reattaching two-dimensional laminar jets and boundary layers are calculated when there is a non-uniform initial velocity profile of non-zero thickness. The pressure calculations are made using the Chapman - Korst model. The results indicate that, as the jet flows downstream, there is a significant transition region in which the behavior corresponding to vanishingly thin initial profile is approached. Accordingly, for jets which reattach within this transition length, bubble pressures are different from those corresponding to reattachment of the asymptotic jet.

G-014

Greenwood, R. J., Ezikiel, F. D.

HYDRAULICS HALF-ADD BINARY NUMBERS

Control Engineering, Page 145, February, 1961

See author Ezikiel, F. D.

G-015

Greenwood, J. R.

THE DESIGN AND DEVELOPMENT OF A FLUID LOGIC ELEMENT

B. S. Thesis, MIT, Mechanical Engineering Dept., May 1960

G-016

Griffin, W. S.

THE ANALYTICAL DESIGN AND OPTIMIZATION OF A PNEUMATIC RATE GYROSCOPE FOR HIGH TEMPERATURE APPLICATIONS

ScD Thesis, MIT, Oct. 3, 1963

G-017

Gurski, R. J., Bails, W. B., Brown, F. T., and Reid, K. N.

RESEARCH AND DEVELOPMENT OF PNEUMATIC JET RELAY SYSTEM FOR PROPULSION  
SYSTEM CONTROL

Dept. of Mechanical Engr., MIT, Report No. DSR-9159-1 dated 3/31/63

See author Bails, W. B.

G-018

Griffith, W.A. and Byrd, J.L.

SYSTEM AND COMPONENT CONSIDERATIONS FOR AN ALL PNEUMATIC MISSILE  
ALTITUDE CONTROL SYSTEM.

U.S. Army Missile Command, Redstone Arsenal, Report No. 63-330,  
dated August, 1963.

Complete guidance and control systems will be developed as a logical consequence of the rate damper system. Two axis rate sensors are being developed and further component development can be expected especially in the areas of gain, repeatability, and increased efficiency. Acceleration, velocity and displacement control will be possible.

H-001

Hall, G. W.

APPLICATION OF BOUNDARY LAYER THEORY TO EXPLAIN SOME NOZZLE  
AND VENTURI FLOW PECULIARITIES

Proc. Instn, Mech. Engrs., Vol. 173#36 1959, Page 837

H-002

Harrison, P.

TESTS ON A TWO DIMENSIONAL MODEL OF AN OIL CONTROL VALVE

Dept. of Scientific and Industrial Research, U. K., Mech. Engr.  
Research Lab., Fluids Report No. 50, 1956

H-003

Hartenberg, R. S., and Denavit, J.

THE FABULOUS AIR COMPRESSOR

Machine Design, Page 168, July 21, 1960

See author Denavit, J.

H-004

Hemmenway, S. F. and Spivak, A. L.

FINAL REPORT ON THE DEVELOPMENT PROGRAM OF THE ADVANCED CONTROL  
COMPONENTS UNIT

USAF Contract AF (600) 38062 and AEC Contract AT (11-1)-171 Jan.  
1962 (General Electric).

This report covering final development work on fluid amplifiers, supplements PREDC 836, entitled "Preliminary Report Development of a Fluid Amplifier." It documents development of a pneumatic servo valve having no moving parts, a special amplifier for high temperature use, and other efforts in connection with this device. Capabilities of the fluid amplifier as a high-reliability servo valve are discussed.

H-005

Henke, Russell W.

#### FLUID AMPLIFIERS SEEK CPI USES

Industrial and Engr. Chemistry, Vol. 55, No. 3, Page 44, March, 1963

In the past three years, DOFL and others, both here and abroad, have explored the concept in greater detail concentrating on defining and evaluating the major variables, most of the financial support has come from the military for missile guidance computers, rocket steering, and the like. One company has demonstrated an application using the amplifier in a pneumatic gogeny setup for quality control.

H-006

Henke, Russell, W.

#### NEW SHAPES FOR FLUID FLIP FLOPS

Machine Design, Vol. 35, Page 150-155, March 14, 1963

Several jet-type fluid amplifiers are currently under study. (1) Jet-interaction type, used for modulating or proportional-type control; operates on the principle of conservation of momentum. (2) Boundary-layer type; a fluid bi-stable flip-flop control element. (3) A proportional amplifier in which output pressure is approximately a linear function of control pressure. (4) Turbulence amplifier of two tubes are positioned in axial alignment and spaced as illustrated, a stream emitting from one tube with laminar flow will enter the second with negligible pressure drop or velocity loss.

H-007

Heskestad, Gunnar

#### MEASUREMENTS IN A TWO-DIMENSIONAL TURBULENT JET

NASA Report N62-12790 (John Hopkins U. Baltimore, Md.)

The measurements were made with a constant temperature hot-wire set in a region for enough downstream to be approximately self-preserving. The results include the lateral distributions of mean stream-wise velocity, together with r.m.s. components, fluctuating velocities and Reynolds shear stress, in coordinates oriented along the streamlines and perpendicular to them. The results are preliminary to the extent of needing corrections for non-linear effects of the hot-wire.



H-008

Hicks, B. A., Jettu, E. S.

PNEUMATIC LINEAR CIRCUITS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I;  
DOFL, Washington, D. C.

The importance of demonstrable analogies between pneumatic and electrical and mechanical systems is that the same kinds of circuit theory can be applied to predict the behavior of a given pneumatic system and to design for desired performance characteristics.

H-009

Hobbs, E. V.

FLUID AMPLIFICATION: LOGIC ELEMENTS

Harry Diamond Lab Report No. TR-1114, March 8, 1963

Descriptions are given of the operation of various fluid logic elements--singly and in combination.

H-010

Hobbs, E. V., Marsh, D. S.

FLUID AMPLIFICATION (8) USE OF EPOXY CASTINGS FOR FLUID AMPLIFIER DESIGN

Astia Report AD-401 319  
DOFL Report TR-1102

An adjustable master unit was used to make a series of cast-epoxy fluid amplifiers that incorporate incremental dimensional changes. Subsequent unit testing identified the best geometry for a given performance requirement. The process provides an inexpensive means of precisely producing the numerous units necessary for empirical design studies.

H-011

Holbrook, E. L.

NEW APPLICATION POTENTIAL WITH PNEUMATIC TECHNIQUES

Automatic Control, Vol. 13, No. 3, Page 32, September, 1960

This article discusses some of the ways in which pneumatics can be utilized to perform functions which used to be the exclusive province of other engineering disciplines. Now that traditional lines of demarkation which separated pneumatics, electricity and hydraulics are disappearing, air is being used to perform many new and basic assignments in the fields of electricity or hydraulics.

H-012

Holmes, A. B., Warren, R. W., Barclay, R. G.

APPLICATION OF FLUID AMPLIFICATION TO ROCKETRY

Diamond Ordnance Fuze Laboratories, Washington, D. C.

See author Barclay, R. G.

H-013

Holmes, Allen B. (DOFL)

ROCKET THRUST VECTORING

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, (DOFL) Washington, D. C.

Paper describes experimental program conducted at DOFL to investigate characteristics of a supersonic fluid amplifier discharging air at high mach numbers into the expansion cone of a rocket nozzle for thrust vector control. Preliminary static firings of a cold gas mach 3.2 nozzle with fluid amplifier controls were made. Direct measurements were made of the amplifier input flow induced lateral thrust and switching levels.

H-014

Horton, B. M.

AMPLIFICATION BY FLUID STREAM INTERACTION

North East Electronics Research and Engineering Meeting (I.R.E.)  
Boston, November 1960

H-015

Horton, H. B.

DELAY LINE MEMORY

U. S. Patent No. 3,075,548 dated January 29, 1963

This invention relates to information storage devices of the type commonly referred to as delay line memories. Provides a fluid delay line memory wherein the read, write, and recirculate functions are all performed in response to fluid control signals.

H-016

Horton, B. M.

NEGATIVE FEEDBACK FLUID AMPLIFIER

U. S. Patent No. 3,024,805

A negative feedback fluid amplifier adapted to provide a substantially constant fluid flow therefrom, comprising a fluid amplifier adapted to issue a main stream of fluid, a fluid feedback path having an opening for receiving and feeding back a portion of said main fluid stream into said amplifier, said fluid feedback path being constructed and arranged such that fluid fed back to said amplifier deflects said main stream so that less fluid flows into said opening and means in said feedback path adapted to smooth out any variations of fluid flow therein.

H-017

Hughes, W. F. and Osterle, J. F.

ON THE ADIABATIC COUETTE FLOW OF A COMPRESSIBLE FLUID

ASME Transaction, Vol. 79, Pages 1313-1316, August, 1957

An investigation is made of the adiabatic flow of air between two parallel plates very close together in relative tangential motion with a pressure differential across the moving plate. The solution predicts the "thermal wedge" effect of hydrodynamically lubricated slider-pad bearings and gives a quantitative analysis of the more general problem where a pressure differential exists across the slider pad.

H-018

Humphrey, R. L., Metzger, E. E.

INSTRUMENTATION FOR RESEARCH AND DEVELOPMENT IN PURE FLUID SYSTEMS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

Some flow and pressure measurements in pure fluid systems can be made with instruments adapted from other fields--others require new types of instruments. Examples of both are discussed.

H-019

Hurvitz, H.

SUCTION AMPLIFIER

U. S. Patent No. 3,001,539

This invention concerns itself with a type of fluid amplifier utilizing no moving parts, in which boundary layer lock-on effects are employed by controlled reduction of pressure in a boundary layer lock-on region, rather than by a control jet. This reduction being effected by means of a channel communicating between the boundary layer interaction region and a region of lower pressure that exists in the power stream itself.

I-001

Iseman, J., Katz, S.

ANGULAR SPEED CONTROL WITH A BISTABLE FLUID AMPLIFIER

Control Engineering, Vol. 10, No. 7, July, 1963

In this experimental system, the blower wheel is driven and loaded, as an impulse turbine, by jets of air directed against its blades. A pneumatic-angular speed sensor determines whether the wheel is moving faster or slower than the desired angular velocity. The sensor transmits this information to a bi-stable fluid amplifier. The output flow of the amplifier then applies corrective action to the wheel.

J-001

Jacobs, E.

S.A.E. AEROSPACE REPORT

Hydraulics and Pneumatics, 14, No. 6, Page 112, June, 1961

Many indications of the swiftly changing state of the fluid-power-in-space art were offered in April to the 50th meeting of S.A.E.'s A-6 Committee on Aerospace Hydraulic and Pneumatic Systems and Equipment. Two papers discussed pure fluid controls using valves and circuits with no moving parts. The first publication of the vortex valve was made by E. M. Dexter of GE. Dr. Bowles of DOFL described the pure fluid power components being developed at the laboratories for digital and logic devices.

J-002

Jensen, R. A., Albertson, M. L., Dai, Y. B. and Rouse, H.

DIFFUSION OF SUBMERGED JETS

Proceedings ASCE, Vol. 74, Part 2, Page 1571

J-003

Jettu, E. S., Hicks, B. A.

PNEUMATIC LINEAR CIRCUITS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

See author Hicks, B. A.

K-001

Kallevig, J. A. and Reilly, R. J.

**FLOW VISUALIZATION AND EXPERIMENTAL STUDIES OF A PROPORTIONAL  
FLUID AMPLIFIER**

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I,  
DOFL, Washington, D.C.

Experimental data taken on a particular type of closed, proportional fluid amplifier did not agree with analysis based on two different mathematical models. Visualization studies and detailed measurement in the interaction region of 3 fluid jets show that the power stream is accelerated after leaving the power nozzle.

K-002

Kalpin, M. A.

**VELOCITY CORRELATION MEASUREMENTS IN THE MIXING REGION OF A JET**

Massachusetts Inst. of Tech. NASA Rpt. N63-16683 dated March, 1963

Measurements of space-time correlations of the u-component of turbulence in the mixing region of a jet are presented. Measurements of the angular correlation function are reported which show no correlation of the fluctuations across the diameter of the jet.

K-003

Kastrov, V. V. and Rogovay, V. M.

**A GYROSCOPE WITH A FLUID ROTOR**

Transl. of Soviet Patent No. 134453 dated January 5, 1960

The design of a gyroscope with a fluid rotor is presented. In this gyroscope, the natural balancing of a rotating fluid which has no rigid connection with the housing of the gyroscope is used as the rotor. In order to accomplish momentless readings, a phosphorescent fluid is used in the gyroscope, which is illuminated through the windows of the chamber. A microscope with a photoelectric system is used to make the readings.

K-004

Katz, Silas (DOFL)

#### AN INTRODUCTION TO PROPORTIONAL FLUID CONTROL

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, (DOFL) Washington, D. C.

The system consists of an active component and passive components. The active component is the proportional fluid amplifier which provides a large fluid output signal that is proportional to a smaller fluid input signal. The passive components which produce their effects solely because of fluid properties and a particular geometry are: pressure, which is analogous to voltage; flow, which is analogous to current; resistance, the magnitude of which depends upon the viscosity of the fluid and the diameter of the orifice; inertance (inductance), the magnitude of which depends upon the length of the tubing and its cross-sectional area; and capacitance, which depends upon the volume of the tank. The function of these passive components is to operate the signal waveform and to produce such effects as an output pressure which is approximately the integral of the input pressure by combining resistance and capacitance. Use of these components has led to the development of an amplifier with measured pressure gains in the neighborhood of 500, by cascading several stages of amplification.

K-005

Katz, S., Iseman, J.

#### ANGULAR SPEED CONTROL WITH A BISTABLE FLUID AMPLIFIER

Control Engineering, Vol. 10, No. 7, July, 1963

See author Iseman, J.

K-006

Katz, S., Peperone, S. J., Goto, J. M.

#### GAIN ANALYSIS OF THE PROPORTIONAL FLUID AMPLIFIER

ASTIA Report AD-296513, October, 1962 (DOFL Report No. TR-1073)

A theoretical analysis of signal gain using principles of fluid stream interaction is presented. The analysis is applied to predict pressure, flow, and power gains of a fluid amplifier and to determine optimum operating conditions and geometry. Comparison of theory and measurements show agreement within the experimental error.



K-007

Katz, S., and Dockery, R. J.

GENERALIZED PERFORMANCE CHARACTERISTICS OF PROPORTIONAL AND  
BISTABLE FLUID AMPLIFIERS

Harry Diamond Lab Report R-RCA-63-13 dated April 17, 1963

See author Dockery, R. J.

K-008

Katzoff, S. and Loving, D. L.

THE FLUORESCENT-OIL FILM METHOD AND OTHER TECHNIQUES FOR  
BOUNDARY-LAYER FLOW VISUALIZATION

NASA Memo 3-17-59L

K-009

Kerr, D. L.

STUDY OF INTERSTAGE GAP PHENOMENA

G.E. Internal Report 58GL70

K-010

Keller, J. B.

TEAPOT EFFECT

J. of Applied Phys. Vol. 28, No. 8, p. 829, 1957

K-011

Keto, Jorma R.

## FLUID AMPLIFICATION. 2. FLOW VISUALIZATION - COMPRESSIBLE FLUIDS

Report No. TR-1041, August 20, 1962, Diamond Ordnance Fuze Laboratories, Ordnance Corps., Department of the Army, Washington 25, D. C.

A study has been made on the methods generally used in flow visualization and their applications to pure fluid systems. Comparison details of the shadowgraph, schlieren, and interferometer techniques are reported; also, a generalized equation is derived for the schlieren method, relating light intensity to gas density for two-dimensional flow. Construction details are presented on two schlieren-type systems, together with illustrated results of typical images obtained.

Improved visualization techniques were realized during this study, using helium, volatile liquids, and condensible vapor. In addition, a technique was developed for sealing interchangeable pure fluid elements to optical windows permitting repeated use without replacing the sealing materials or cleaning windows.

Additional data will be issued on the basic principles and techniques applicable to pure fluid systems.

K-012

Klanfer, L. and Owen, P. R.

## ON THE LAMINAR BOUNDARY LAYER SEPARATION FROM THE LEADING EDGE OF A THIN AEROFOIL

A.R.C. Current Paper No. 220, 1955

K-013

Klass, Phillip J.

## IBM LAB TAPS EUROPEAN SCIENCE SKILLS

Aviation Week and Space Technology, Vol. 78, No. 14, April 8, 1963

IBM currently is studying hydraulic logic elements which have no moving mechanical parts and depend upon interaction of jets with boundary walls. The IBM scientists concede that hydraulic or pneumatic computers are not likely to replace the electronic types for most applications, but they point out that the non-electronic type logic may be well suited for use in industrial or aerospace applications where hydraulic or pneumatic power is used for the process to be controlled. One such application might be rocket boosters where the fuel could be used for computation-control prior to serving its primary function.

K-014

Kline, S. J. and Moore, C. A.

SOME EFFECTS OF VANES AND TURBULENCE IN TWO-DIMENSIONAL WIDE-ANGLE  
SUBSONIC DIFFUSERS

Tech. Note Nat'l, Adv. Comm. Aero., Wash., No. 4080, 1958

K-015

Knight, H., Allen, C. W.

ELECTRO-PNEUMATIC TRANSLATOR

U. S. Patent No. 3,072,147

See author Allen, C. W.

K-016

Kompass, E. J.

THE STATE OF THE ART IN FLUID AMPLIFIERS

Control Engineering, Vol. 10, No. 1, Page 88, January, 1963

Report on the first symposium on fluid amplification held since the Army's Diamond Ordnance Fuze Lab announced the no-moving parts fluid devices 3 years ago. Basics, Development, Progress, Application, and Reliability are discussed, plus a new principle that may speed application.

K-017

Korst, H. H., Mueller, T. J., and Chow, W. L.

ON THE SEPARATION REATTACHMENT, AND REDEVELOPMENT OF INCOMPRESSIBLE  
TURBULENT SHEAR FLOW

Journal of Basic Engineering, Paper No. 63, March, 1963

See author Chow, W. L.

K-018

Krassor, I. M., Radovskii, L. I. and Turbin, B. G.

A TWO-STAGE HYDRAULIC AMPLIFIER WITH NOZZLE DAMPERS AND VALVE

Russian Engineering Journal, Vol. XLI, No. 6, 1961

This article deals with the analysis of the statics of hydraulic amplifiers, explains the method of calculating static characteristics and gives the basis for choosing certain parameters and the controlling element of the amplifier.

K-019

Krassor, I. M. and Turbin, B. G. (Moscow)

JET POWER EFFECT IN NOZZLE-FLAPPER HYDRAULIC AMPLIFIERS

Automation and Remote Control, Vol. 20, No. 12, Page 1589, December, 1959

The experimental results are given for an investigation of a hydraulic amplifier of the nozzle-flapper type for various combinations of its parameters. Basic attention was paid to the power interaction of the jet and the flapper. A short description is given of the objects tested, the program, the setup, and the methods of carrying out the tests.

K-020

Krassor, I. M.

SENSITIVITY OF HYDRAULIC NOZZLE-FLAPPER AMPLIFIERS

Automation and Control, Page 491, September, 1962

K-021

Krassor, I. M., Radovskii, L. I., and Turbin, B. G.

THE EFFECT OF THE CHARACTERISTICS OF AN ELECTRICAL ELEMENT ON THE CHOICE OF THE PARAMETERS FOR A HYDRAULIC AMPLIFIER

Automation and Control, Vol. 21, No. 12, December, 1960

This paper provides a basic analysis of the computation of the initial pressure in the chamber between restrictors in a hydraulic amplifier of the jet-damper type which is controlled by an electro-magnetic element; the characteristics of the latter taken into account.

K-022

V. Krzywoblocki, M. Z.

JETS A REVIEW OF LITERATURE

Jet Propulsion, Vol. 26, No. 9, p. 760, 1959

K-023

Krzywoblocki, M. Z.

ON STEADY, LAMINAR TWO-DIMENSIONAL JETS IN COMPRESSIBLE  
VISCIOUS GASES FOR BEHIND THE SLIT

Quarterly Applied Mathematics 7, 313 (1949)

K-024

Kuehn, D. M., Larson, H. K., and Chapman, D. R.

INVESTIGATION OF SEPARATED FLOWS IN SUPERSONIC STREAMS WITH  
EMPHASIS ON THE EFFECT OF TRANSITION

Tech. Note Nat'l Adv. Comm. Aero, Washington, No. 3869, 1957

K-025

Kuether, A. M.

INVESTIGATION OF THE TURBULENT MIXING REGIONS FORMED BY JETS

Journal of Applied Mechanics, Trans. of the ASME, Vol. 57,  
1935, Page 87

L-001

Ladenburg, R., Winckler, J. and Van Voorhis, C. C.

INTERFEROMETRIC STUDIES OF FASTER THAN SOUND PHENOMENA

Phys. Rev. Vol. 73, No. 11 (1948), p. 1359

L-002

Lanin, N. D.

PNEUMATIC CALCULATING MACHINES AS A MEANS OF ENSURING THE  
RELIABILITY OF INTEGRATED AUTOMATIC SYSTEMS

Preprint of International Federation of Automatic Control Congress,  
Page No. 1101

The pneumatic calculating device developed at the Central Scientific Research Institute of Complex Automation is of high accuracy, simple construction and high operating reliability. The pneumatic controlling machine described is constructed on the basis of these elements and is of the highest reliability and should be widely applied in integrated automatic-systems.

L-003

Larson, H. K., Kuehn, D. M., and Chapman, D. R.

INVESTIGATION OF SEPARATED FLOWS IN SUPERSONIC AND SUBSONIC STREAMS  
WITH EMPHASIS ON THE EFFECT OF TRANSITION

Tech. Note Nat'l Adv. Comm. Aero, Washington, No. 3869, 1957

L-004

Lechner, T. J., Wambsganss, M. W.

PROPORTIONAL POWER STAGES FOR IMPEDANCE MATCHING PURE FLUID DEVICES

Proceedings of the Fluid Amplification Symposium, October, 1962,  
Vol. I, DOFL, Washington, D. C.

This paper is concerned with proportional pure fluid amplifiers of the three dimensional type. This type is based on the interaction of two streams: a supply or power stream and a single or control stream. The principle of operation of such a pure fluid amplifier is a transfer of momentum at the point of intersection of the two streams. The supply stream is deflected by the control stream and a proportionate amount of pressure is collected at the output.

L-005

Lees, L. and Crocco, L.

A MIXING THEORY FOR THE INTERACTION BETWEEN DISSIPATIVE FLOWS  
AND NEARLY ISENTROPIC STREAMS

Journal of the Aeronautical Sciences, Vol. 19, 1952 - Pages 649-676

See author Crocco, L.

L-006

Leibowitz, Howard

THE EFFECT OF GEOMETRIC PARAMETERS ON THE STATIC PERFORMANCE OF  
AN AXI-SYMMETRIC JET MODULATOR

Course II S.B. May 1963

The results of several experiments to determine the static performance of an axially aligned jet-receiver-diffuser as a function of receiver geometry are presented. The receiver configuration involved was that of a diffuser with a constant area inlet passage followed by a diverging conical section. The lengths of the constant diameter tested were 0, 1, 2, 3 and 5 diameters.

L-007

Lequornik, D. J. and Curtiss, H. A.

RESEARCH STUDIES IN PROPORTIONAL FLUID STATE CONTROL COMPONENTS

Giannini Controls Corp. Report ARD-TR-013-01 dated September 1963

See author Curtiss, H. A.

L-008

Lequornik, D. J., and Curtiss, H. A.

RESEARCH STUDIES IN PROPORTIONAL FLUID STATE CONTROL COMPONENTS

Final Report Contract, DA 36-034-ORD-3722RD, Redstone Arsenal,  
Ala. (Giannini Controls Corp.)

See author Curtiss, H. A.

L-009

Lettendre, R. P., and Barlow, G. R.

**EXPERIMENTAL STUDY OF THE SEPARATION POINT AND SEPARATION BUBBLE**

Thesis for Bachelor of Aeronautical Engr., Catholic University of America, Washington, D. C., June 1959

L-010

Levin, S. G., Manion, F. M.

**JET ATTACHMENT DISTANCE AS A FUNCTION OF ADJACENT WALL OFFSET AND ANGLE**

Harry Diamond Laboratories Report TR-1087, December 31, 1962, AD-297 895

Attachment of a submerged incompressible, two-dimensional, turbulent jet to an adjacent straight wall (Coanda effect) is analyzed. Parametric equations are developed that predict the point at which the jet attaches as a function of wall angle and offset distance. Computer solutions were obtained for several sets of conditions. Experiments were conducted with both air and water jets at mach 0.5 equivalent and results agree well with corresponding computer solutions when the jet spread parameter is also treated as a function of offset distance and wall angle.

L-011

Lewellen, W. S.

**A SOLUTION FOR THREE-DIMENSIONAL VORTEX FLOWS WITH STRONG CIRCULATION**

NASA Report N63-16491, May, 1962, Aerospace Corp. - Research Lab

The Navier-Stokes equations for a viscous, incompressible fluid are considered for a steady, axisymmetric flow composed of a strong rotation combined with radial sink flow which exhausts axially inside a finite radius. The equations are reduced to two coupled partial differential equations in terms of the stream function and circulation.



L-012

Linderoth, E. T.

**AERODYNAMIC CHECK VALVE**

U. S. Patent No. 2,727,535 dated December 20, 1955

This invention relates to an aerodynamic check valve type of nozzle or a combination of gas nozzles having such a shape that the resistance of flow in one direction, the reverse direction, is so much greater than in the opposite or forward direction, that the nozzle operates as a non-return or check valve, if it is connected to a gas chamber in which the pressure in one way or another is caused to pulsate, for instance, by intermittent heating or alternatively cooling, or both of a gaseous medium contained in said chamber.

L-013

Loving, D. L. and Katzoff, S.

**THE FLUORESCENT-OIL FILM METHOD AND OTHER TECHNIQUES FOR BOUNDARY-LAYER FLOW VISUALIZATION**

NASA Memo 3-17-59L

See author Katzoff, S.

M-001

MacLellan, G. D. S., Mitchell, A. E., Turnbull, D. E.

FLOW CHARACTERISTICS OF PISTON-TYPE CONTROL VALVES

Proc. Symposium on Recent Mechanical Engineering Developments in Automatic Control Inst. Mech. Engineers, London 1960

M-002

Mamzic, C. L.

TINY JETS REPLACE MOVING PARTS IN PROCESS-CONTROL DEVICES

Iron Age, May 23, 1963

Among the new solid-state pneumatics and hydraulic devices are noncontact dimensional gaging switches, basic amplifiers, oscillators, pulse counters, logic function blocks and process-control valves. All of these devices, in various stages of development at Moore Products Co., have no moving parts. Operation is based entirely upon the interaction of fluid streams.

M-003

Mamzic, C. L.

USING PNEUMATIC ANALOG COMPUTING ELEMENTS FOR CONTROL

Control Engineering, Vol. 8, No. 4, Page 105, April, 1961

Many opportunities exist in process operations for incorporating computer operations in the control scheme. When the particular application is relatively small and well-defined, reliable pneumatic analog devices offer a low-cost, profitable way of achieving computing control. The needed computation is obtained by proper interconnection of simple pneumatic analog computing elements that can perform arithmetic linearizing, differentiating, integrating, and logic function.

M-004

Manion, F. M., Levin, S. G.

JET ATTACHMENT DISTANCE AS A FUNCTION OF ADJACENT WALL OFFSET AND ANGLE

Harry Diamond Lab Report TR-1082 (AD-297 895) December 31, 1961

See author Levin, S. G.

M-005

Manion, Francis M.

JET INTERACTION IN A DEFINED REGION

MME Thesis, Dept. Mech-Aero Engr. - Catholic University, Washington, D. C.,  
March, 1962

The problem presented deals with the interaction of two jet streams in a defined interaction region. The deflection of a power jet by the normal addition of a control jet is investigated. A two dimensional analysis is developed which relates the direction of the resultant stream to the input momentum ratio and the geometry of the interaction region.

M-006

Mann, R. W.

STEREOPHOTOGRAMMETRY APPLIED TO HYDRAULIC ANALOGUE STUDIES OF  
UNSTEADY GAS FLOW

MIT Dept. of Mech. Engr., No. 8543-1, 1962

M-007

Markstein, G. H., and Foa, J. V.

THEORETICAL ANALYSIS OF FLOW PHENOMENA IN A PULSE JET

Cornell Aeronautical Lab Proj. SQUID, Semi-Annual Prog. Rpt., Jet  
Propulsion Engines, 1952

M-008

Marsh, David S., and Hobbs, Edward V.

FLUID AMPLIFICATION (8) USE OF EPOXY CASTINGS FOR FLUID AMPLIFIER DESIGN

ASTIA Report AD-401 319, DOFL Report TR-1102

See author Hobbs, E. V.

M-009

Marwood, Robert M. Jr.

AN EXPERIMENTAL INVESTIGATION OF THE COANDA EFFECT

Purdue University, Engineering Experiment Station, Project No. M-156  
dated February 1949, ASTIA Report ATI-80261

The Coanda effect in a fluid-flow phenomenon in which fluid constrained to two-dimensional flow and discharged from a rectangular or annular slot will be deflected from its initial direction to flow along the flap. Results are presented of an experimental investigation to determine the entrainment characteristics and efficiencies of a Coanda slot and single flap.

M-010

Mass. Inst. of Tech., Dynamic Analysis and Control Lab

BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL FOR THE UNITED STATES AIR FORCE

Report No. 59-491, AD-229,465 (1 Feb-31 May 59) Progress Report No. 2,  
(Contract AF33(616) 6120)

This report describes continuing applied research and development work on vital problems encountered in providing high performance hydraulic and pneumatic control systems for advanced system design and development. Increased emphasis on high pressure pneumatic components and systems reflects approach to an ultimate objective of employing hot gas power to operate such systems. Control valves, servo-motors, gas bearings, and techniques of control are the major items discussed in this report.

M-011

Mass. Inst. of Tech., Dynamic Analysis and Control Lab

BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL FOR THE UNITED STATES AIR FORCE

Progress Rept. No. 3, 1 June - 30 Sept 59, AD-232 965 (Contract AF33  
(616)6120)

This report describes continuing applied research and development work on vital problems encountered in providing high performance hydraulic and pneumatic control systems for advanced system design and development. Increased emphasis on high pressure pneumatic components and systems reflects approach to an ultimate objective of employing hot gas power to operate such systems. Control valves, servo-motors, gas bearings and techniques of control are the major items discussed in this report.

M-012

Mass. Inst. of Technology, Dynamic Analysis and Control Lab

**BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL FOR THE UNITED STATES AIR FORCE**

Dynamic Analysis and Control Lab., MIT, Progress Report No. 4, 66 p, Sep 60, (AD-248 889) (Contract AF33(616)6120)

This report describes continuing applied research and development work on vital problems encountered in providing high performance hydraulic and pneumatic control systems for advanced system design and development. Increased emphasis on high pressure pneumatic components and systems reflects approach to an ultimate objective of employing hot-gas power to operate such systems. Control valves, servomotors, gas bearings, and techniques of control are the major items discussed in this report.

M-013

Mass. Inst. of Tech., Dynamic Analysis and Control Lab

**BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL FOR THE UNITED STATES AIR FORCE**

Progress Rept. No. 5, November, 1960, AD-250 267 (Contract AF33(616)6120)

Research and development is continuing on problems associated with high performance hydraulic and pneumatic control equipment for advanced systems. Increased emphasis on high pressure pneumatic components and systems reflects the approach to the ultimate objective of employing hot gas power to operate such systems. Control valves, servomotors, gas bearings, fluid power and signal transmission, hot-gas contamination, techniques of control are the major items discussed.

M-014

Mass. Inst. of Tech., Dynamic Analysis and Control Lab.

**BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL FOR THE UNITED STATES AIR FORCE**

Progress Rept. No. 6, March, 1961, AD-257 722 (Contract AF33(616)6120)

The development of high performance hydraulic and pneumatic control equipment for advanced systems is discussed. Increased emphasis on high pressure pneumatic components and systems reflects the approach to an ultimate objective of employing hot-gas power to operate such systems. Control valves, relays, servomotors, gas bearings, fluid power and signal transmission, hot-gas contamination, hot-gas gyros, and techniques of control are treated.

M-015

Mass. Inst. of Tech, Dynamic Analysis and Control Lab.

**BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL FOR THE UNITED STATES AIR FORCE**

Mass. Inst. of Tech., Dynamic Analysis and Control Lab. Progress Rept. No. 7, August, 1961, TR 61-179, AD-267 050 (Contract AF33(616)6120)

Work on problems vital to the design and development of high performance hydraulic and pneumatic control equipment for advanced systems is described. Increased emphasis on high pressure pneumatic components and systems reflects the approach to an ultimate objective of employing hot-gas power to operate such systems. Control valves, relays, servomotors, gas bearings, fluid power and signal transmission, hot-gas contamination, hot-gas gyros, and techniques of control are discussed.

M-016

Mass. Inst. of Tech., Dynamic Analysis and Control Lab.

**BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL**

Dynamic Analysis and Control Lab., MIT, Progress Report No. 8, Feb 62, 158 p., (AD-291 653) (Contract AF33(616)6120)

Continuing applied research and development work on problems vital to the design and development of high performance hydraulic and pneumatic control equipment for advanced systems is described. Increased emphasis on high pressure pneumatic components and systems reflects the approach to an ultimate objective of employing hot gas power to operate such systems. Control valves, servomotors, gas bearings, fluid power and signal transmission, hot-gas contamination and techniques of control are discussed.

M-017

Mass. Inst. of Technology, Dynamic Analysis and Control Lab

**BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL FOR THE UNITED STATES AIR FORCE**

Dynamic Analysis and Control Lab., MIT, Progress Report N. 9, January, 1962, 61 p (AD-298 611) (Contract AF33(616)6120)

M-018

Mass. Inst. of Tech., Dynamic Analysis and Control Lab

**BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL FOR THE UNITED STATES AIR FORCE**

MIT Report No. 1 (1 Oct 61-31 Jan 62) 105 p. AD-290 321 (Contract AF33 (657)7535)

Continuing applied research work on problems related to the design and development of high performance hydraulic and pneumatic control equipment for advanced systems is described. Sustained emphasis on high pressure pneumatic components and systems reflects a desired ultimate objective of employing hot-gas power to operate such systems. Included in this report are descriptions of work on a reaction-jet servo system and study of friction drag on reaction-jet motors; experimental studies of a flapper valve in a breadboard pneumatic servomechanism; development of transmission line theory; fluid jet relays; and a step-by-step actuator for a pulsed pneumatic information transmission system; cold gas tests of a hot-gas rate gyro; and flow characteristics of small orifices.

M-019

Mass. Inst. of Technology, Dynamic Analysis and Control Lab

**BASIC APPLIED RESEARCH IN FLUID POWER CONTROL**

MIT Progress Report No. 2, 1 Feb - 31 May 62 (AD-298 984)  
(Contract AF33 (657)7535)

M-020

Mass. Inst. of Technology, Dynamic Analysis and Control Lab

**BASIC RESEARCH AND DEVELOPMENT IN FLUID POWER CONTROL FOR THE UNITED STATES AIR FORCE**

MIT Third Progress Report, 47 p, February, 1963 (AD-401 192)  
(Contract AF33(657)7535)

Continuing applied research and development work on problems related to the design and development of high performance hydraulic and pneumatic control equipment for advanced aerospace systems are described. Sustained emphasis on high pressure pneumatic components and systems reflects a desired objective of employing gas power to operate systems which must operate under a wide range of operating temperatures, and/or in fields of high intensity radiation. Included in this report are descriptions of work on Design of Rotors for Reaction Jet Servomotors; Fluid Jet Amplifiers with no-moving parts; Characteristics of Conventional Pneumatic Jet-Pipe Valves; Jet-Pipe Valve Stability; A Rate Gyroscope for Operation with Hot Gases; and Gas Lubricated Bearings, and Characteristics of Short-Tube Orifices.

M-021

Matthews, C. W.

THE DESIGN, OPERATION AND USES OF THE WATER CHANNEL AS AN  
INSTRUMENT FOR THE INVESTIGATION OF COMPRESSIBLE-FLOW PHENOMENA

NACA TN 2008

M-022

McArdle, J. G.

INTERNAL CHARACTERISTICS AND PERFORMANCE OF AN AERODYNAMICALLY  
CONTROLLED VARIABLE DISCHARGE CONVERGENT NOZZLE

NACA-TN-4312

The effective flow area of a convergent exhaust nozzle was reduced by injecting a high-pressure secondary jet into the nozzle near the exit. Analytical expressions relating the performance with significant design and operating variables were developed and necessary experimental factors were evaluated by using a 4-inch exit diameter nozzle with unheated pressurized air discharged to the atmosphere.

M-023

McArdle, J. G.

INTERNAL CHARACTERISTICS AND PERFORMANCE OF SEVERAL JET DEFLECTORS  
AT PRIMARY-NOZZLE PRESSURE RATIO UP TO 3.0

NACA TN 4264, June 1958

M-024

McMahan, K. D.

"FLUIDYNAMIC" CONTROL OF FLUID FLOW

Proceedings of the Fifth International Congress for Applied  
Mechanics held at MIT, Sept. 12-16, 1938

In the past, many flow control functions have been performed by the mechanical movement of valves, dampers, louvres, shutters and other similar devices. Now it is possible with simple structure to perform some of these functions without the use of movable mechanical parts. These new devices employ the dynamics of the fluid itself to perform the control functions in response to certain changes in the fluid system. The term "fluidynamic" control has been applied to such devices.



M-025

Metral, A., and Zerner, F.

L'EFFECT COANDA

Publ. Sci. Min. Air., (218) (Ministry of Aviation Translation publication No. TIB/T4027), 1958

M-026

Metral, A.

L'EFFECT COANDA

Proc. 5th International Congress of Applied Mechanics, 1938, Page 256

M-027

Metral, A.

SUR UN PHENOMENE DE DEVIATION DES VEINES FLUIDES ET SES APPLICATIONS  
(EFFECT COANDA)

Proc. Fifth Inst. Congr. Appl. Mech. p.456, 1938; AMC Wright Field, Dayton, Ohio, Translation #F-TS-823-RE(1948) ASTIA ATI #18833.

M-028

Metral, A. R. and Coanda H.

THE COANDA EFFECT

Final Report USAF Contract AF61(514)1409 (Contract between A.R.D.C. Brussels and SFERI-Coanda, Clichy, France)

See author Coanda, H.

M-029

Metzger, E. E., Humphrey, R. L.

INSTRUMENTATION FOR RESEARCH AND DEVELOPMENT IN PURE FLUID SYSTEMS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

See author Humphrey, R. L.

M-030

Miller, D. P., and Olsen, R.

#### AERODYNAMIC STUDIES OF FREE AND ATTACHED JETS

United Aircraft Corp., Research Laboratories, A-1771-24, October 1963,  
Available from Dept. of Commerce, Office of Technical Services,  
Wash. 25, D. C.

M-031

Mitchell, A. E. Dr.

#### CALCULATING WITH JETS

New Scientist, Vol. 17, No. 329, March 7, 1963

The logical operations required for digital computing can be carried out using one jet of air or water to deflect or alter another. Small, reliable devices carrying out such operations in about a millisecond may find application in accounting machines and in the control of industrial processes.

M-032

Mitchell, A. E., MacLellan, G. D. S., Turnbull, D. E.

#### FLOW CHARACTERISTICS OF PISTON-TYPE CONTROL VALVES

Proc. Symposium on Recent Mechanical Engineering Developments in  
Automatic Control Inst. Mech. Engineers, London 1960

See author MacLellan, G. D. S.

M-033

Mitchell, A. E., Glaettli, H. H., Mueller, H. R.

#### FLUID LOGIC DEVICES AND CIRCUITS

IBM Research Paper RZ-99, September 20, 1962, Zurich Research Lab.,  
Ruschlikon, Zurich (Transl. Society of Inst. Technology, Feb. 26,  
1963) Switzerland

A review of fluid logic devices is given. The devices are classified into two main groups depending on whether or not they utilize movable or deformable mechanical parts. Some general comparisons and a discussion of the governing and limiting parameters are made in the text. General examples of circuits are given to illustrate the techniques used in their design and fabrication. Fabrication methods, instrumentation and applications are discussed in the concluding sections of the paper.

M-034

Mitchell, A. E.

LOGICAL OPERATIONS WITH INTERACTING FLUID JETS

IBM Research Report RZ-84, April 24, 1962, Zurich Research Lab.,  
Adliswil, Zurich, Switzerland

Methods of performing logical operations in fluid systems by means of interacting fluid jets are described. A historical survey of the reported work is given in the introduction. The elements described in the text have either two or three input flows. Logical operations may be performed with only one or with connected elements are given. A summary of some design considerations for these elements and their possible use when connected with other amplifying fluid logic devices are made in the conclusion.

M-035

Mitchell, A. E., Mueller, Dr. H. R., Glaettli, H. M., Comparin, Dr. R. A.

ON THE LIMITATIONS AND SPECIAL EFFECTS IN FLUID JET AMPLIFIERS

ASME Symposium Report on Fluid Jet Control Devices, November 28, 1962

See Comparin, Dr. R. A.

M-036

Mitchell, A. E.

REATTACHMENT OF SEPARATED BOUNDARY LAYERS AND THEIR EFFECTS IN FLUID SWITCHING DEVICES

IBM Research Report RZ-81, February 19, 1962, Zurich Research Lab.,  
Adliswil, Zurich, Switzerland

A description of phenomena associated with the reattachment and separation of fluid jets and their effects in various fluid devices is given. The way these phenomena can be used and the way in which they influence the performance of fluid switching devices is described.

M-037

Mon, G., Nunn, D. E., Capt., Woodward, K. E., Barila, T. G.,

A FLUID-AMPLIFIER ARTIFICIAL HEART PUMP

Proceedings of the Fluid Amplification Symposium, October 1962, Vol. I  
DOFL, Washington, D. C.

See author Barila, T. G.

M-038

Moore, C. A. and Kline, S. J.

SOME EFFECTS OF VANES AND TURBULENCE IN TWO-DIMENSIONAL WIDE-ANGLE  
SUBSONIC DIFFUSERS

Tech. Note Nat'l, Adv. Comm. Aero., Wash., No. 4080, 1958

M-039

Moorhead, John G., Barclay, Ralph G., Bowers, Allen A.

FLUID AMPLIFICATION 10. USE OF THE HYDRAULIC ANALOGY IN THE STUDY  
OF FLUID-INTERACTION DEVICES

Harry Diamond Lab ASTIA Report No. TR-1098, also AD-405 867

See Barclay, R. G.

M-040

Morgan, P. G.

HIGH SPEED FLOW THROUGH PERFORATED PLATES

Journal-Royal Aero. Society, Vol. 64, No. 590, PP. 103-105 (Tech Notes)  
February, 1960

The flow through porous screens has been widely studied from both the theoretical and experimental points of view. The most widely used types of screen are the wire mesh and the perforated plate and the majority of the literature has been concerned with the former.

M-041

Moynihan, F. A., Reilly, R. J.

NOTES ON A PROPORTIONAL FLUID AMPLIFIER

ASME Symposium Report on Fluid Jet Control Devices dated November 28, 1962

The experimental output versus input, the experimentally derived velocity profiles and the visualization studies all detract from the validity of the submerged jet analogy as applied to the fluid amplifier. A modification of the inviscid model to account for the contraction of the power stream should be examined.

M-042

Mueller, H. R. Mitchell, A. E., Glaettli, H. H.

FLUID LOGIC DEVICES AND CIRCUITS

IBM Research Paper RZ-99, September 20, 1962 (Transl. Society of Inst. Tech. Feb. 26, 1963) Switzerland

See Mitchell, A. E.

M-043

Mueller, Dr. H. R., Glaettli, H. M., Comparin, Dr. R. A., Mitchell, Dr. A. E.

ON THE LIMITATIONS AND SPECIAL EFFECTS IN FLUID JET AMPLIFIERS

See author Comparin, R. A. (Dr.)

M-044

Mueller, T. J., Korst, H. H., and Chow, W. L.

ON THE SEPARATION, REATTACHMENT, AND REDEVELOPMENT OF INCOMPRESSIBLE TURBULENT SHEAR FLOW

Journal of Basic Engineering, Paper N. 63, March, 1963

See author Chow, W. L.

M-045

Mueller, H. R.

THE HYDRAULIC OSCILLATOR

IBM RESEARCH REPORT RZ-68 dated 9/22/61, Zurich Research Lab, Adliswil, Zurich, Switzerland

This report gives a short description of the working principle of the oscillator and a rough procedure is given to calculate frequency and maximum stroke. The hydraulic oscillator has less cavitation than a multivibrator, but frequency is much lower. In Appendix I, the formulae for the viscous losses in a rigid tube with oscillating pressure gradient is derived.

M-046

Murphy, J. S.

SOME EFFECTS OF SURFACE CURVATURE ON LAMINAR BOUNDARY-LAYER FLOW

Journal of Aeronautical Sciences, May 1953

N-001

Newman, B. G. and Borques, C.

REATTACHMENT OF A TWO-DIMENSIONAL INCOMPRESSIBLE JET TO AN  
ADJACENT FLAT PLATE

Aeronautical Quarterly, Vol. XI, August, 1960

See author Borques, C,

N-002

Newman, B. G.

THE DEFLECTION OF PLANE JETS BY ADJACENT BOUNDARIES--COANDA EFFECT

Boundary Layer and Flow Control, pp. 232-264, Edited by G. V.  
Lackmann, Vol. I, Pergamon Press, New York, 1961

N-003

Newton, G. C. Jr. (MIT)

THEORY AND PRACTICE IN VIBRATORY RATE GYROS

Control Engineering, Vol. 10, No. 6, June, 1963

The vibratory gyro has attracted much interest because of its potential long life, ruggedness, and simplicity. Here is the state-of-the-art with theory explained in terms of coriolis forces and related to conventional rate gyros, but concentrates his analysis on the tuning fork configuration which has received the most attention from experimenters. Theoretical capabilities and practical limitations are discussed.

N-004

Norwood, R. E.

A PNEUMATIC FLAPPER VALVE STUDY

Preprint of First International Federation of Automatic Control  
Congress Paper, Page No. 572 (Moscow, 1960)

The first part of this paper is a theoretical analysis of the behavior of a fixed volume filled with gas connected to a flapper valve. Three different models of the system were studied: an isentropic model, a perfect mixing model, and an imperfect mixing model. Using the isentropic model, it is shown that for the best pressure sensitivity the downstream to upstream area ratio should be about 1.25. The second part describes some experiments in which the force on the flapper by a flapper valve was measured.

N-005

Norwood, Dr. R. E.

A PERFORMANCE CRITERION FOR FLUID JET AMPLIFIERS

ASME Symposium Report on Fluid Jet Control  
Devices--dated November 28, 1962

Concerned with the bistable type of amplifier in which the job has two stable positions. Proportional devices are not considered. Evaluation of the performance of a fluid jet amplifier in order that the elements can be properly designed and interconnected. Performance criterion selected is the input impedance of the device. Experimental data shown to illustrate method.

N-006

Nunn, D. E. Capt., Woodward, K. E., Barila, T. G. Lt. Col.,  
Mon, G., Straub, H. H.

A FLUID-AMPLIFIER ARTIFICIAL HEART PUMP

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I,  
DOFL, Washington, D. C.

See Barila, T. G.



O-001

Olsen, R., and Miller, D. P.

AERODYNAMIC STUDIES OF FREE AND ATTACHED JETS

United Aircraft Corp., Research Laboratories, A-1771-24, October 1963,  
Available from Dept. of Commerce, Office of Technical Services,  
Wash. 25, D. C.

O-002

Olson, R. E.

AN ANALYTICAL AND EXPERIMENTAL STUDY OF TWO-DIMENSIONAL COMPRESSIBLE  
SUBMERGED JETS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. 1,  
DOFL, Washington, D. C.

Analytical and experimental studies of compressible, two-dimensional  
turbulent submerged jets were conducted with air as the working fluid.  
A theoretical flow model is presented and a momentum integral analysis  
is developed based on this flow model.

O-003

Olson, R. E.

CHARACTERISTICS OF TWO-DIMENSIONAL COMPRESSIBLE ATTACHED JETS

Proceedings of the Fluid Amplification Symposium, October, 1962,  
Vol. I, DOFL, Washington, D. C.

Analytical and experimental studies of the characteristics of  
two-dimensional, compressible jets attached to an adjacent boundary  
wall were conducted with air as the working fluid. A theoretical flow  
model is presented and methods for predicting the jet characteristics  
based on this model are discussed.

0-004

Olson, Robert E.

FLUID AMPLIFICATION

United Aircraft Corp., East Hartford, Conn. Interim Rept. No. 6 on  
Aerodynamic Studies of Pure-Pneumatic Systems, 12 Oct 62 AD-297-023

A study is reported of the aerodynamic characteristics of two-dimensional compressible jets both unbounded and bounded. An objective of the work is to establish quantitative procedures for predicting (1) flow profiles at various stations and (2) the pressure recovery of receiving apertures.

0-005

Olson, R. E.

REATTACHMENT OF A TWO-DIMENSIONAL COMPRESSIBLE JET TO AN ADJACENT  
PLATE

ASME Symposium Report (Fluid Jet Control Devices), November 28, 1962

The analytical approach employed in this paper should be quite useful in that it not only handles set-back of the side-walls, but also accounts for slope of the side-walls in the same analysis. In addition, the insertion of empirical constants  $K_1$  and  $K_2$  permit ready modification of the theory to get close agreement with test results.

0-006

Osterle, J. E. and Hughes, W. F.

ON THE ADIABATIC COUETTE FLOW OF A COMPRESSIBLE FLUID

ASME Transaction, Vol. 79, Pages 1313-1316, August 1957

See author Hughes, W. F.

0-007

Owen, P. R. and Klanfer, L.

ON THE LAMINAR BOUNDARY LAYER SEPARATION FROM THE LEADING EDGE OF A  
THIN AEROFOIL

A.R.C. Current Paper No. 220, 1955

P-001

Pai, S. I.

FLUID DYNAMICS OF JETS

D. Van Nostrand Company, New York, 1954

P-002

Palmisano, R. R.

FLUID AMPLIFIER DEMONSTRATION VEHICLE

Proceedings of the Fluid Amplification Symposium, October, 1962,  
Vol. I, DOFL, Washington, D. C.

A jet-propelled vehicle has been built which demonstrates the practicability of fluid-amplification for thrust vectoring. An account is also given of a 5-stage proportional fluid amplifier which is capable of amplifying control signals over 100,000 times.

P-003

Pay, R. G.

NEW DEVELOPMENTS IN PNEUMATIC COMPUTERS

Engineer Materials and Design, Vol. 5, No. 7, Pages 513-14

The basic elements of a recently developed fluid amplifier are shown. The author suggests that computers will soon be available. In view of their insensitivity to high temperatures and nuclear radiation, there is already a significant demand for them and approximately 20 companies in the U.S.A. are now concerned with their development. Details of some of the operating characteristics of the computers are given together with descriptions of the necessary manufacturing tolerances and power requirements.

P-004

Pay, R. G.

#### PNEUMATIC LOGIC

Process Control and Automation, Page 479, November, 1961

Pneumatic computers operating at basic frequencies of 10-100 kc/s are under development. The relatively low cost, extreme ruggedness, and minute size of the basic components suggest that when used with parallel computation the pneumatic machines will be competitive with electronic computers in medium-speed applications.

P-005

Peperone, S. J., Warren, R. W.

#### FLUID AMPLIFICATION. 1. BASIC PRINCIPLES

Report No. TR-1039, Diamond Ordnance Fuze Laboratories, Ordnance Corps., Department of the Army, Washington 25, D. C., August 15, 1962

See Author R. W. Warren

P-006

Peperone, S. J., Katz, S., Goto, J. M. (DOFL)

#### FLUID AMPLIFICATION - GAIN ANALYSIS OF THE PROPORTIONAL FLUID AMPLIFIER

ASTIA Report AS-296 513, October, 1962 (DOFL Report No. TR-1073)

See author Katz, S.

P-007

Powell, Alan

#### CHARACTERISTICS AND CONTROL OF FREE LAMINAR JETS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

Describes some relevant basic features of laminar incompressible jet flows as a separate element free of the effects of adjacent solid walls. The characteristics of the steady flow are well established, theoretically and experimentally.

P-008

Powell, A. and Chanaud, R. C.

EXPERIMENTS CONCERNING THE SOUND SENSITIVE JET

J. Acoust. Society Am. Vol. 34, No. 7, 1962

See author Chanaud, R. C.

P-009

Powell, Alan

FLUID MOTION AND SOUND

California U., Los Angeles, Annual summary Rept., 1 May 59-30  
Apr. 60, Report No. 60-51 (AD 239-941)

Summaries of papers on the following topics are reported:  
Instability of Jets; Edge Tones; Aeolian Tones; Turbulent Jet  
Noise; Boundary Layer Noise; and Propagation Problems.

P-010

Powell, Alan

NATURE OF THE FEEDBACK MECHANISM IN SOME FLUID FLOWS PRODUCING SOUND

California U., Los Angeles, Presented at the Fourth International  
Congress on Acoustics, 21-28 August 1962, Copenhagen (AD-289 696)

P-011

Powell, A.

VORTEX ACTION ON EDGETONES

J. Acoust. Society Am. Vol. 34, 1962

R-001

Radovskii, L. I., Krassor, I. M., and Turbin, B. G.

A TWO-STAGE HYDRAULIC AMPLIFIER WITH NOZZLE DAMPERS AND VALVE

Russian Engineering Journal, Vol. XLI, No. 6, 1961

See author Krassor, I. M.

R-002

Radovskii, L. I. Turbin, B. G., and Krassor, I. M.

THE EFFECT OF THE CHARACTERISTICS OF AN ELECTRICAL ELEMENT ON  
THE CHOICE OF THE PARAMETERS FOR A HYDRAULIC AMPLIFIER

Automation and Control, Vol. 21, No. 12, December 1960

See author Krassor, I. M.

R-003

Rauch, W. T. and Stern, H.

FLUID COMPUTATION AND CONTROL SYMPOSIUM

GE Lab Report 63GL115, August 12, 1963

On May 15 and 16, 1963, a symposium was held at Schenectady on the subject of Fluid Transistors, their design, application and manufacture. This report contains the transcript of the papers and a group discussion on the general topic of fluid computation and control.

R-004

Redding, T. H.

FLOW CHARACTERISTICS OF METERING NOZZLES

The Engineer, July 26, 1963

R-005

Reed, W. E.

PNEUMATIC CONTROL OF TURBOJET VARIABLE NOZZLE

Control Engr. 1956, October, Vol. 3, No. 10, Pages 92-99

Many operating functions of a turbojet engine perform well when controlled by pneumatics. Author describes one of these functions, the control of a variable area nozzle using all-pneumatic control and actuation. He shows: (1) How to automatically adjust the nozzle during afterburner; (2) How to obtain stable control operation; (3) How to set up interlock functions.

R-006

Reethof, G., Shearer, J. L., and Blackburn, J. F.

FLUID POWER CONTROL

Publ. Technology Press, M.I.T. and Wiley, New York, 362 pp. (book), 1960

R-007

Reid, K. N., Jr.

OPTIMUM DESIGN PARAMETERS OF A PNEUMATIC JET-PIPE VALVE

This paper presents experimental pressure-flow-displacement relationships for a conventional jet-pipe valve operating with compressed air. The ratio of the jet-pipe nozzle diameter to the receiving hole diameter, the jet-pipe nozzle to receiving hole spacing, and the pressure level of the jet-pipe supply are discussed as to their effect on the overall characteristics of the valve.

R-008

Reid, K. N., Gurski, R. J., Bails, W. B., and Brown, F. T.

RESEARCH AND DEVELOPMENT OF PNEUMATIC JET RELAY SYSTEM FOR PROPULSION SYSTEM CONTROL

Dept. of Mechanical Engr., MIT, Report No. DSR-9159-1 dated 3/31/63

See author Bails, W. B.

R-009

Reilly, R. J. and Kallevig, J. A.

FLOW VISUALIZATION AND EXPERIMENTAL STUDIES OF A PROPORTIONAL  
FLUID AMPLIFIER

Proceedings of the Fluid Amplification Symposium, October 1962,  
Vol. I, DOFL, Washington, D. C.

See author Kallevig, J. A.

R-010

Reilly, R. J.

INDUCTION FLUID AMPLIFIER

U. S. Patent No. 3,030,979 dated April 24, 1962

This invention is directed to a unique type of induction fluid amplifier or element that utilizes the viscous forces existing between flowing fluids and associated fluids or fixed partitions. More specifically, the present invention is directed to a fluid flow element or system that utilizes no moving parts in control of a main fluid stream by the use of an inducing controlled fluid stream.

R-011

Reilly, R. J., Moynihan, F. A.

NOTES ON A PROPORTIONAL FLUID AMPLIFIER

ASME Symposium Report on Fluid Jet Control Devices dated November 28, 1962

See author Moynihan, F. A.



R-012

Riordan, H. E.

#### HIGH SPEED PNEUMATIC DIGITAL OPERATIONS WITH MOVING ELEMENTS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

Kearfott first became interested in pneumatic digital computers in conjunction with a feasibility study on an all-pneumatic guidance system. Such a system is of interest for applications presenting a severe thermal or radiation environment. Digital data processing was selected for the pneumatic system because it presented no accuracy limitations (as opposed to analog computation), and because it was felt that the digital approach offered greater flexibility of application and design.

R-013

Riordan, H. E. (Kearfott)

#### PNEUMATIC DIGITAL COMPUTER

Instruments and Control Systems, Vol. 34, Page 1260, July, 1961

Pneumatic devices can be built with response time comparable to electronic components and higher packing density. A pneumatic digital computer can operate in temperatures to 2000°F, and in any radiation environment. A bistable element which operates on compressed air or gas has a switching time as short as ten microseconds and can be packaged at 3000/cubic inch.

R-014

Robinson, S. T. and Sproule, R. S.

#### THE "COANDA EFFECT"

ASTIA Report ATI-60515

Data obtained by interrogation of M. Henri Coanda and members of the Societe Coanda are presented. The purpose of the interrogation consisted in the possibilities of practical application of the Coanda theory to jet propulsion. It is believed that Coanda has obtained static thrust figures which at their best give considerably more augmentation to a jet than any of the standard methods. However, full-scale results have not been obtained. Coanda has invented a rotary vacuum pump which has given good test results but is not yet mechanically developed.

R-015

Roderick, W. E. B.

USE OF THE COANDA EFFECT FOR THE DEFLECTION OF JET SHEETS OVER  
SMOOTHLY CURVED SURFACES

Part II, University of Toronto, UTIA TN #51

R-016

Rogovay, V. M., and Kastrov, V. V.

A GYROSCOPE WITH A FLUID ROTOR

Transl. of Soviet Patent No. 134 453 dated January 5, 1960

See author Kastrov, V. V.

R-017

Rouse, H., Albertson, M. L., Dai, Y. B. and Jensen, R. A.

DIFFUSION OF SUBMERGED JETS

Proceedings ASCE, Vol. 74, Part 2, Part 2, Page 1571

See author Albertson, M. L.

S-001

Sawyer, R. A.

THE FLOW DUE TO A TWO-DIMENSIONAL JET ISSUING PARALLEL TO A FLAT PLATE

Journal of Fluid Mechanics, Vol. 9, Part 4, December, 1960

An experiment has been performed to determine the cavity pressures and cavity length for the flow under a curved two-dimensional turbulent jet discharging parallel to a flat plate at some distance from the surface. The measurements agree quite closely with the predictions of a simple analysis of the flow when a value is assigned to the spread parameter for the curved jet which is somewhat different from that for the plane jet.

S-002

Schaefer, J. W.

AN ELECTRICALLY OPERATED HYDRAULIC CONTROL VALVE

Bell Syst. Tech. J., Vol. 36, p. 711, 1957

S-003

Schaffer, Allan B.

ON-OFF PULSED TRANSMISSION LINE FOR PLASMA PROPULSION

Aerospace Corp., El Segundo, Calif., 8 Mar 61, AD-269 184

Huddleston's analysis of on-off pulsed operation of the rail plasma driver is extended to the transmission line-type plasma driver. Both the mode of operation in which the distributed capacitors of the transmission line are originally uncharged and the one in which they are originally charged are analyzed. Theoretically on-off pulsed operation affords the possibility of achieving high efficiencies with either mode of operation. From a practical standpoint, however, the mode with capacitors originally uncharged is seen to be the most feasible.

S-004

Schardin, H.

DAS TOEPLERSCHE SCHLIERENVERFAHREN

Forschungsheft V.D.I. 367, Ansgalie B, Band 5(July-August,1934)

S-005

Schlichting, H.

BOUNDARY LAYER THEORY

McGraw Hill, 1955

S-006

Schrenk, Ing. E.

VERSUCHE UBER STROMUNGSARTEN, VENTILWIDERSTAND UND VENTILBELASTUNG

Forschungsarbeiten auf dem Gebiet des Ingenieurwesens, Heft 272, 1925  
(B.H.R.A. Abbreviated Translation Publication No. T. 547)

S-007

Semikora, A. I., and Zalmanson, L. A.

INVESTIGATION OF THE CHARACTERISTICS OF PNEUMATIC JET ELEMENTS

Automation and Remote Control, Vol. 20, No. 4, Page 431, April, 1959

The article deals with an investigation of pneumatic jet elements, the operation of which is based on the utilization of the characteristics of pressure changes obtained when the impact tube is moved through different sections of the jet flowing from a nozzle. Examples are given of the possible applications of such elements in pneumatic devices.

S-008

Severson, A. M.

FLUID AMPLIFIER

U. S. Patent No. 3,080,886 dated March 12, 1963

The object of this invention is to disclose a novel type of fluid amplifier that is capable of controlling the flow of a fluid in a manner which distributes the fluid in one or more of a plurality of outlets. Also, to disclose a fluid amplifier that can be used to create turbulence of flow between the inlet and outlet to thoroughly mix one or more fluids fed into an inlet manifold or to separate inlets. This device is also capable of being step controlled so that fluid can be directed into a plurality of paths from a single inlet.

S-009

Sferi-Coanda

FINAL REPORT

Contract No. AF 61(514)1409, ASTIA AD 204073, 1957

S-010

Sferi-Coanda

FINAL REPORT, VOL. II

Contract No. 61 (514)1409, ASTIA AD 204074

S-011

Shapiro, A. and Forstall, W. Jr.

MOMENTUM AND MASS TRANSFER IN COAXIAL GAS JETS

Journal of Applied Mechanics, Dec. 1950, Page 399

See author Forstall, W. Jr.

S-012

Shapiro, A. H.

THE DYNAMICS AND THERMODYNAMICS OF COMPRESSIBLE FLOW

Vol. 1, p. 59-68, Roland Press

S-013

Shearer, J. Lowen

BIBLIOGRAPHY OF FLUID POWER CONTROL IN THE D.A.C.L. FROM FEBRUARY  
1954 TO JUNE 1959

Dynamic Analysis and Control Lab., MIT, July 1959, 9 p, AD-226 047

A complete listing of reports and papers written in the Dynamic Analysis and Control Laboratory on Fluid Power Control Research and Development work during the five-year period 1954 - 1959. Fluid Power Control as used here refers to work on high performance hydraulic and pneumatic control systems especially in relation to problems of automatic flight control.

S-014

Shearer, J. L., Reethof, G., and Blackburn, J. F.

FLUID POWER CONTROL

Publ. Technology Press, M.I.T. and Wiley, New York, 362 pp. (Book),  
1960

S-015

Shearer, J. L.

RESISTANCE CHARACTERISTICS ON CONTROL ORIFICES

Proc. Symposium on Recent Mech. Eng'r. Developments in Automatic  
Control, Inst. Mech. Engrs. Lond., 1960

S-016

Sheeran, W. J., and Dosanjh, D. S. (Syracuse University)

EXPERIMENTS WITH TWO-DIMENSIONAL, TRANSVERSELY IMPINGING JETS

Reprint from AIAA Journal, February, 1963, Vol. I, No. 2

See author Dosanjh, D. S.

S-017

Sheeran, W. J. and Dosanjh, D. S. (Syracuse University)

INTERACTING JET FLOW INVESTIGATIONS PART I FURTHER EXPERIMENTS WITH TWO-  
DIMENSIONAL UNDEREXPANDED, TRANSVERSELY IMPINGING JET FLOWS

Syracuse University Research Institute - Dept. of ME - Report No.  
ME1058-63091 (February 1963)

See author Dosanjh, D. S.

S-018

Sheeran, W. J., Dosanjh, D. S.

INTERACTION OF TRANSVERSELY IMPINGING JETS

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I,  
DOFL, Washington, D. C.

See author Dosanjh, D. S.

S-019

Sherrill, W. M., Cooper, R. E.

SOME CURRENT REQUIREMENTS OF MILITARY CONTROL SYSTEMS

Proceedings of the Fluid Amplification Symposium, October, 1962,  
Vol II, DOFL, Washington, D. C.

See author Cooper, R. E.

S-020

Shinn, J. N. Dr.

FLUID AMPLIFIERS--THEIR STATUS AND SOME APPLICATIONS

Paper presented at the Society of Automotive Engineers Sub-  
Committee, A-6C, Miami, Florida, 5/6/63

Describes the characteristics of fluid amplifiers, developmental  
status and identification of some present and planned applications  
of fluid amplifier systems.

S-021

Shinn, J. N. Dr., Boothe, W. A.

A SUGGESTED SYSTEM OF SCHEMATIC SYMBOLS FOR FLUID AMPLIFIER CIRCUITRY

Proceedings of the Fluid Amplification Symposium, October, 1962,  
Vol. I., DOFL, Washington, D. C.

See author Boothe, W. A.

S-022

Sigalla, A.

EXPERIMENTAL DATA ON TURBULENT WALL JETS

Aircraft Engineering, May 1958

S-023

Silver, S., Bartz, D. R. and Elliott, D. G.

CALCULATION OF TURBULENT BOUNDARY-LAYER GROWTH AND HEAT TRANSFER  
IN AXI-SYMMETRIC NOZZLES

J.P.L. Tch. Report #32-387 dated Feb. 15, 1963

S-024

Simmons, F. S.

ANALYTIC DETERMINATION OF THE DISCHARGE COEFFICIENTS OF FLOW NOZZLES

NACA TN-3447

S-025

Simson, A. K.

A THEORETICAL STUDY OF THE DESIGN PARAMETERS OF SUBSONIC PRESSURE  
CONTROLLED, FLUID JET AMPLIFIERS

Ph.D. Thesis - Dept. of Mechanical Engineering, MIT, July 15, 1963

A subsonic pressure controlled, fluid jet amplifier is analyzed to determine the important design parameters; once these parameters are known, they are considered in terms of stability, linearity and gain, to determine the optimum design configurations. Water table experiments and observations are used to help determine the proper analytical models.

S-026

Snediker, R. A., Donaldson, C.

EXPERIMENTAL INVESTIGATION OF THE STRUCTURE OF VORTICES IN SIMPLE  
CYLINDRICAL VORTEX CHAMBERS

NASA Report N63-12987 dated December, 1962

See author Donaldson, C.

S-027

Speiser, A. P.

HYDRAULIC SWITCHING DEVICES

IBM Research Report RZ-80 dated 1/31/62, Zurich Research Lab, Adliswil,,  
Zurich, Switzerland

Two all-fluid logic systems are described, the first using spool valves as switches, the second employing dynamic phenomena involving no moving (or deformable) solid parts. Both schemes may be operated with liquid or gas. Parameters determining size, power consumption, and speed are given.



S-028

Spivok, A. L. and Hemmenway, S. F.

FINAL REPORT ON THE DEVELOPMENT PROGRAM OF THE ADVANCED CONTROL  
COMPONENTS UNIT

General Electric Co. Report APEX-666, Part 2, January 1962

This report covering final development work on fluid amplifiers, supplements PREDC 836, entitled, "Preliminary Report Development of a Fluid Amplifier." It documents development of a pneumatic servo valve having no moving parts, a special amplifier for high temperature use, and other efforts in connection with this device. Capabilities of the fluid amplifier as a high-reliability servo valve are discussed.

S-029

Sproule, R. S. and Robinson, S. T.

THE COANDA EFFECT

Combined Intelligence Objectives Sub-Committee, Air Material  
Command, Wright Field, Dayton, Ohio, October-November 1944, ASTIA  
ATI No. 60515

See author Robinson, S. T.

S-030

Stenning, A. H.

AN EXPERIMENTAL STUDY OF TWO-DIMENSIONAL GAS FLOW THROUGH VALVE-TYPE  
ORIFICES

Amer. Soc. Mech Engrs. Paper No. 54 A-45, 1954

S-031

Stern, H., and Rauch, W. T.

FLUID COMPUTATION AND CONTROL SYMPOSIUM

GE Lab Report 63GL115, August 12, 1963

See author Rauch, W. T.

S-032

Stinning, A. H.

AN EXPERIMENTAL STUDY OF TWO-DIMENSIONAL GAS FLOW THROUGH VALVE-TYPE ORIFICES

Amer. Soc. Mech. Engrs. Paper No. 54 A-45

S-033

Stone, J. A.

AN INVESTIGATION OF DISCHARGE COEFFICIENTS AND STEADY-STATE FLOW FORCES FOR A POPPET-TYPE VALVE

S. M. Thesis, Dept. Mech. Eng'r. M.I.T., Cambridge, Mass., 1957

S-034

Stone, J. A.

DISCHARGE COEFFICIENTS AND STEADY-STATE FLOW FORCES FOR HYDRAULIC POPPET VALVES

Amer. Soc. Mech. Engrs. Paper No. 59 HYD-18, 1959

S-035

Stong, C. L.

HOW STREAMS OF WATER CAN BE USED TO CREATE ANALOGUES OF ELECTRONIC TUBES AND CIRCUITS

Scientific American, Page 128, August, 1962

A high school student, M. O. Meetze, set out to devise an improved analogue of the triode vacuum tube. Meetze sought a working model in which nothing moved except a fluid representing the electric current. He not only designed and built such a model, but also used it in a series of experiments that led to the construction of a fluid diode, a fluid oscillator and a variety of hydraulic "circuits," including one that has no electronic counterpart.

S-036

Stratford, B. S.

A FURTHER DISCUSSION ON MIXING AND THE JET FLAP

Aeronautical Quarterly, Vol. VII, August 1956

S-037

Straub, H. H., Mon, G., Nunn, D. E. Capt., Woodward, K. E.,  
Barila, T. G., Lt. Col.

A FLUID-AMPLIFIER ARTIFICIAL HEART PUMP

Proceedings of the Fluid Amplification Symposium, October, 1962,  
Vol. I, DOFL, Washington, D. C.

See author Barila, T. G.

S-038

Straub, Henrik H.

ENGINEERING ANALYSIS OF THE ARMY ARTIFICIAL HEART PUMP (MODEL O)

DOFL, Washington, D. C., 29 Oct 62, 30 p., AD-289 064

An initial engineering analysis was made of the Army Artificial Heart Pump, Model O. The analysis demonstrates that the pump's output varies directly with propelling and filling pressures and inversely with circuit resistances in a manner similar to that of the human heart. The systolic pressure amplitude and pulse duration of the pump's output pulses can be varied within fairly broad limits. It is determined that the heart pump, using 0.020-in. thick, 85-durometer, polyvinylchloride ventricles can satisfy the design requirements for human perfusion, although pulse rates are low at high loads. Ventricles of slightly greater stiffness are required to match more exactly cardiovascular characteristics. For animal perfusions, ventricles of much greater stiffness or perhaps a different design are required. The functional capabilities of the pump apart from the ventricle appear to be satisfactory.

T-001

Tal', A., Berezovets, G. T., and Dimitrier, V. M.

A NEW TYPE OF PNEUMATIC COMPUTER

Automation and Remote Control, Vol. 22, No. 1, August, 1961,  
Page 93

See author Berezovets, G. T.

T-002

Tal', A., Aizerman, M.

NEW DEVELOPMENTS IN PNEUMOAUTOMATION

Paper presented at International Federation on Automatic Control,  
September, 1963 at Zurich, Switzerland

See author Aizerman, M.

T-003

Tal', A. A., and Berends, T. K. (Moscow)

PNEUMATIC SWITCHING CIRCUITS

Automation and Remote Control, Vol. No. 20, November, 1959,  
Page 1446

See author Berends, T. K.

T-004

Tanaka, K.

AIRFLOW PAST ENGINE VALVES

Report Aero. Res. Inst. Tokyo, Imp. Univ. Vol. 4, No. 50, pp. 259-  
360 and No. 51, pp. 361-424, 1929 (in English)

T-005

Tesla, N.

#### VALVULAR CONDUIT

U. S. Patent No. 1,329,559 dated February 3, 1920

This patent consists in the employment of a peculiar channel or conduit characterized by valvular action. This invention can be embodied in many constructions greatly varied in detail, but for the explanation of the underlying principle, it may be broadly stated that the interior of the conduit is provided with enlargements, recesses, projections, baffles, or buckets which, while offering virtually no resistance to the passage of the fluid in one direction, other than surface friction constitute an almost impossible barrier to its flow in the opposite sense by reason of the more or less sudden expansions, contractions, deflections, reversals of direction, stops and starts and attendant rapidly succeeding transformations of the pressure and velocity energies.

T-006

Thompson, P. A.

#### RESONANCE TUBES

MIT Thesis dated December, 1960

A simple resonance tube consists of a cylinder, one end of which is closed, the other end open. A jet of gas directed axially against the open end may excite the gases within the tube to violent oscillation. Straight or periodic supersonic jets are most effective for this excitation. Timed shadowgraphs of the external flow have been made. Transducer pressure records at the open and closed ends of the tube have been obtained. External flow is temporarily steady during the tube inflow and outflow phases.

T-007

Todd, K. W.

#### MECHANICAL RELAY OF THE FLUID JET TYPE

U. S. Patent No. 2,408,705

T-008

Tsui, Ka Cheung, Belsterling, C. A.

RESEARCH ON THE PERFORMANCE OF PURE FLUID AMPLIFIERS PART I STATIC  
OR LOW FREQUENCY CASE

Franklin Inst. Laboratories, Interim Report No. I -0976101  
dated February 1963 to August 1963

See author Belsterling, C. A.

T-009

Tu, Yih-O, and Cohen, H.

A THEORETICAL MODEL FOR SEPARATION IN THE FLUID JET AMPLIFIER

IBM - Journal of Research and Dev., Vol. 7, No. 4, October 1963

See author Cohen, H.

T-010

Tucker, M.

APPROXIMATE CALCULATION OF TURBULENT BOUNDARY-LAYER DEVELOPMENT  
IN COMPRESSIBLE FLOW

NACA TN-2337, April 1951

T-011

Turbin, B. G., Radovskii, L. I., and Krassor, I. M.

A TWO-STAGE HYDRAULIC AMPLIFIER WITH NOZZLE DAMPERS AND VALVE

Russian Engineering Journal, Vol. XLI, No. 6, 1961

See author Krassor, I. M.

T-012

Turbin, B. G., and Krassor, I. M. (Moscow)

JET POWER EFFECTS IN NOZZLE-FLAPPER HYDRAULIC AMPLIFIERS

Automation and Remote Control, Vol. 20, No. 12, December 1959 (Page 1589)

See author Krassor, I. M.

T-013

Turbin, B. G., Radorskii, L. I., and Krassor, I. M.

THE EFFECT OF THE CHARACTERISTICS OF AN ELECTRICAL ELEMENT ON THE  
CHOICE OF THE PARAMETERS FOR A HYDRAULIC AMPLIFIER

Automation and Control, Vol. 21, No. 12, December 1960

See author, Krassor, I. M.

T-014

Turnbul, D. E., Mitchell, A. E., MacLellan, G. D. S.

FLOW CHARACTERISTICS OF PISTON-TYPE CONTROL VALVES

Proc. Symposium on Recent Mechanical Engineering Developments in  
Automatic Control Inst. Mech. Engineers, London 1960

See author MacLellan, G. D. S.

T-015

Turnbul, D. E.

SOME CHARACTERISTICS OF HYDRAULIC PISTON-TYPE CONTROL VALVES IN  
RELATION TO THEIR USE AS COMPONENTS IN A FEEDBACK POSITION CONTROL  
SYSTEM

Ph.D. Dissertation Camb. Univ., England, 1956

T-016

Tutuer, F. B. and Gibson, J. E.

CONTROL SYSTEM COMPONENTS

McGraw Hill, 1958

See author Gibson, J. E.

U-001

U. S. Army Missile Command, Redstone Arsenal

EXPERIMENTAL DESIGN OF A FLUID-CONTROLLED HOT-GAS VALVE

Report No. RE-TR-62-9 dated Dec. 31, 1962, also N63 19598

This report describes an effort toward development of a hot gas jet reaction valve utilizing boundary layer techniques to control a high pressure, high temperature gas stream. The result of this work has been the successful design of a hot gas valve in a reaction control system utilizing fluid-controlled bistable amplifier principles and requiring no moving parts.



V-001

Van Koevering, A. R.

EXPERIMENTAL LOAD CHARACTERISTICS OF FLUID-JET AMPLIFIERS

Thesis--MS, MIT, August, 1962

The experimental load-flow characteristics of fluid jet amplifiers with both single-control ports and double control ports are presented. A pneumatic model was used and the effects of a supersonic jet at various supply pressures, a subsonic incompressible jet, and the position of the attachment wall or walls were investigated and should be negligible with the proper design; the graphical techniques of matching source and load characteristics are illustrated and their usefulness in the design of fluid jet amplifiers is emphasized.

V-002

Van Tilburg, R. W., Cochran, W. L.

FABRICATION OF FLUID AMPLIFIERS BY OPTICAL FABRICATION TECHNIQUES

Corning Glass Co. First 9 Mo Progress Report ending Dec. 31, 1962 for Harry Diamond Lab Contract No. DA-49-186-ORD-1076

See author Cochran, W. L.

V-003

Van Tilburg, R. W.

PRODUCTION OF FLUID AMPLIFIERS BY OPTICAL FABRICATION TECHNIQUES

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

Results of a study of the applicability of optical fabrication techniques to the production of fluid amplifiers are presented. Results indicate that it is possible to fabricate the complex fluid amplifier designs rapidly and relatively inexpensively.

V-004

Van Voorhis, C. C., Winckler, J. and Ladenburg, R.

INTERFEROMETRIC STUDIES OF FASTER THAN SOUND PHENOMENA

Phys. Rev. Vol. 73, No. 11(1948), p. 1359

See author Ladenburg, R.

V-005

Vermeulen, P. J.

AN INVESTIGATION INTO THE FUNDAMENTALS OF OPERATION AND CHARACTERISTICS  
OF A KINETIC VALVE

M. Sc. Thesis, Victoria Univ, Manchester, 1958

V-006

Voedisch, Alfred Jr.

ANALYTICAL INVESTIGATION OF THE COANDA EFFECT

ASTIA Doc. No. ATI-9881, dated April 3, 1947. Classification changed to  
unclassified 6/18/56.

A partial analytical study has been made of the phenomenon, and the device (called the Coandadevice) needed to produce the phenomena. All suggested applications have been studied, and the relative advantage shown as compared to units now in use. An investigation of the losses prevalent in both the thrust augmenting device and the high-lift low-drag wing are noted, and the relative value of each application is cited in comparison to other well-known methods.

V-007

von Glahn, U. H.

USE OF THE COANDA EFFECT FOR OBTAINING JET DEFLECTION AND LIFT WITH  
A SINGLE FLAT PLATE DEFLECTION SURFACE

Tech. Note Nat'l Adv. Comm. Aero, Wash., No. 4272, 1958

V-008

Von Glahn, U. H.

USE OF THE COANDA EFFECT FOR JET DEFLECTION AND VERTICAL LIFT WITH  
MULTIPLE-FLUTE PLATE AND CURVED PLATE DEFLECTION SURFACES

Tech. Note Nat'l Adv. Comm. Aero., Wash., No. 4377, 1959

W-001

Wadey, W. G.

FLUID KEYBOARD USING JET PIPE VALVES

U. S. Patent No. 3,005,533 dated October 24, 1961

This invention relates to fluid operated mechanical keyboard of the type used in adding machines, typewriters, and other similar devices. More particularly, the present invention related to mechanically actuated keyboard devices of the type which produce fluid output signals when an operator depresses a key. The keyboard disclosed in this patent is limited to the use of a gaseous fluid as the working medium.

W-002

Wadey, W. G.

PNEUMATIC KEYBOARD

U. S. Patent No. 3,034,628 dated May 15, 1962

Object of this invention was to provide a pure fluid system for inserting information into a fluid data processing device. Also an object is to provide a keyboard device for inserting data signals into a fluid data processing device, said keyboard having no moving parts.

W-003

Wadey, W. G.

PROGRAM CONTROL DEVICES FOR FLUID APPARATUS

U. S. Patent No. 3,076,473 dated February 5, 1963

This invention relates to means for controlling and varying the internal operations of a fluid apparatus by changing fluid circuits external of the main body of the apparatus to be controlled. More particularly, the present invention provides program control devices for fluid apparatus, said program control devices being quickly and easily interchanged for the purpose of varying the internal operations of the fluid apparatus.

W-004

Wadey, W. G.

WEB FEEDING DEVICE

U. S. Patent No. 3,075,697 dated 1/29/63

This invention relates to a means for moving tapes, sheets, or similar web-like materials. Provides a fluid operated means for controlling the rate of acceleration of web-like materials to obtain variable but controlled velocities of the web. More particularly, it is the object of this invention to provide a fluid mechanism, which is responsive to fluid signals for controlling the speed and the rate of acceleration of the web material, said fluid mechanism being more economical, faster in response, and more even in application of fluid forces than previous devices.

W-005

Wambsganss, M. W., Lechner, T. J.

PROPORTIONAL POWER STAGES FOR IMPEDANCE MATCHING PURE FLUID DEVICES

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I., DOFL, Washington, D. C.

See author Lechner, T. J.

W-006

Warren, R. W., Barclay, R. G., Holmes, A. B.

APPLICATION OF FLUID AMPLIFICATION TO ROCKETRY

Diamond Ordnance Fuze Laboratories, Washington, D. C.

See author Barclay, R. G.

W-007

Warren, R. W., Peperone, S. J.

#### FLUID AMPLIFICATION. 1. BASIC PRINCIPLES

Report No. TR-1039, August 15, 1962, Diamond Ordnance Fuze Laboratories, Ordnance Corps, Department of the Army, Washington 25, D. C.

Studies made on pure fluid amplification have resulted in an overall program for design and development of fluid amplifiers, both bistable and proportional with no moving parts.

Both flow and pressure at the receiving apertures of the proportional-type device depend on the power jet strength and flow direction. The energy controlled in the amplifier is an order of magnitude larger than the controlling energy. If the walls are relatively close to the interaction region, the stream has a marked tendency to attach to one of the walls. This wall-attachment phenomenon causes the fluid stream to shift completely from one output to the other in response to a control jet pulse, thereby permitting bistable operation. For a proportional unit, the walls are positioned much farther out to minimize the wall effect.

Specifically covered in this report are the effects of the wall and splitter positions in bistable operation, and an analysis of the gain for proportional operation.

W-008

Warren, R. W.

#### FLUID AMPLIFICATION. 3. FLUID FLIP FLOPS AND A COUNTER

Report No. TR-1061, August 25, 1962, Diamond Ordnance Fuze Laboratories, Ordnance Corps., Department of the Army, Washington 25, D. C.

The operating principles of a single-input, fluid-operated flip flop which employs no moving mechanical parts are explained in detail. The principles of the dual-input flip flop are reviewed, and the discussion is extended to the single-input case. Staging is discussed and an example of cascaded staging in fluid binary counter is given.

W-009

Warren, R. W.

#### FLUID-OPERATED TIMER

U. S. Patent No. 3,093,306

This invention relates to a fluid-operated timer which is capable of indicating predetermined time intervals. The fluid-operated timer of this invention incorporates the combination of a fluid-operated oscillator, a fluid operated binary counter and a fluid-operated AND component. The fluid oscillator counter and AND component require no moving parts other than the working fluid employed therein for their operation.

W-010

Warren, R.W.

#### FLUID PULSE CONVERTER

Patent No. 3,001,698 dated 10/5/60

A fluid binary counter adapted to count a series of successive fluid pulses received from a source of pulsed fluid signals comprising a series of fluid pulse converters, each converter having an input tube and a pair of output tubes, said converters being constructed and arranged, so as to switch fluid flow into certain of said output tubes when sequential fluid pulses are received by the input tube of the first converter comprising the series and indicator means actuated by fluid issuing from said output tubes.

W-011

Warren, R. W.

#### PULSE DURATION MODULATION

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

An all-fluid pulse-duration modulation system, which accepts fluid signals proportional to missile error is described. The system consists of a feedback-type oscillator driving a buffer amplifier which, in turn, drives the output bistable amplifier. All of the output of the bistable amplifier issues out of one output at a time, either the left or the right, and can be used as a reaction jet for purposes of control. If the error of the missile is sensed with a gyro, an air jet from the gyro can be divided between two adjacent orifices when the missile is on course, and as it deviates from the true course the flow will be more to one orifice than to the other. This variation can be fed into the left and right control inputs of the pulse duration modulation system. The control inputs are connected to the capacitors on the bistable amplifier. As the control signal on one side increases, the control signal on the other side will decrease.

W-012

Warren, R. W.

#### SOME PARAMETERS AFFECTING THE DESIGN OF BISTABLE FLUID AMPLIFIERS

ASME Symposium Report on Fluid Jet Control Devices dated November 28, 1962

Characteristics of two bistable fluid amplifiers which approximate the two extremes--one very stable (low gain) and one subject to oscillation (high gain). The wall interaction amplifier is designed around the velocity and pressure profiles of the streams. Because of the velocity and pressure profiles of the stream are modified by the presence of the walls, the units are designed around the modified profiles.

A three stage bistable fluid amplifier has been made combining the features of the two extreme units--a unit where high gain and high energy recovery are important.

W-013

Warren, R. W. (DOFL)

#### WALL EFFECT AND BINARY DEVICES

Proceedings of the Fluid Amplification Symposium, October, 1962, Vol. I, DOFL, Washington, D. C.

There are two approaches to fluid amplification. In the first approach, the large power jet is deflected by a small control stream. The amount of deflection being proportional to the momentum of the streams. The second method is to use the entrainment characteristics of the stream and bounding walls to effect the deflection.

W-014

Warren, W. R.

#### AN ANALYTICAL AND EXPERIMENTAL STUDY OF COMPRESSIBLE FREE JETS

Princeton University, Aeronautical Engineering Laboratory, Rept. #381, 1957

W-015

Weeks, T. M. and Dosanjh, D. S.

INTERACTION BETWEEN AN ADVANCING SHOCK WAVE AND OPPOSING JET FLOW

AIAA Journal, Vol. 1, No. 7, July, 1963

See author Dosanjh, D. S.

W-016

Weinstein, A. S.

DIFFUSION OF MOMENTUM FROM FREE AND CONFINED SLOT JETS INTO MOVING  
SECONDARY STREAMS

Carnegie Institute of Technology AFCRC TN-55-476, May 4, 1955

W-017

Wilcox, K. and Braithwaite, R. C.

MECHANICAL RELAY OF THE FLUID JET TYPE

U. S. Patent No. 2,408,603

See author Braithwaite, R. C.

W-018

Williams, James G. Byrd, J. L.

STATIC PRESSURE DISTRIBUTION ALONG AN INCLINED, SETBACK PLATE WITH  
ATTACHED JET USING THE HYDRAULIC ANALOGY

U. S. Army Missile Command Redstone Arsenal, Alabama. RG-TR-63-15.  
Available from Defense Document Center, Cameron Station, Alexandria,  
Va. 22314

See author Byrd, J. L.

W-019

Winckler, J., Van Voorhis, C. C. and Ladenburg, R.

INTERFEROMETRIC STUDIES OF FASTER THAN SOUND PHENOMENA

Phys. Rev. Vol. 73 No. 11(1948), p. 1359

See author Ladenburg, R.



W-020

Wing, W. G. (Sperry Gyroscope Co.)

PROS AND CONS ON FLUID ROTOR GYROS

Published in Control Engineering, Pages 105-109, March 1963

The spinning body in a gyroscope need not be solid as it is conventionally. A spinning mass of fluid offers a number of advantages in simplicity, inherent balance, long life, and low cost. So there is much development along several conceptual lines, and one fluid rotor gyro has already reached the marketplace. Still, respectable problems in design and instrumentation must be solved before fluids can replace solid rotors in all gyro applications. And other exotic approaches (which will be subjects of future articles) might also limit the use of fluid rotors.

W-021

Wood, O. L., Fox, H. L.

A SURVEY OF FLUID DEVICES FOR AUTOMATIC CONTROL SYSTEMS

Paper presented at 6th Region IEEE Technical Conference, April 26, 1963, (Sperry, Utah Co.)

See author Fox, H. L.

W-022

Woodward, K. E., Barila, T. G., Lt. Col., Nunn, D. E., Capt., Mon, G., Straub, H. H.

A FLUID AMPLIFIER ARTIFICIAL HEART PUMP

Proceedings of the Fluid Amplification Symposium, October 1962, Vol. I., DOFL, Washington, D. C.

See Barila, T. G.

Y-001

Yeaple, F.

NO MOVING PARTS FOR FLUID AMPLIFIERS

Product Engineering, Vol. 31, No. 11, March 17, 1960

A new fluid amplifier just unveiled at the Army's Diamond Ordnance Fuse Lab. This new device which uses either gas or liquid and has no moving parts, has a power jet that is deflected to the desired output chamber by directing a control stream against the side of the jet; advantages: construction is simple, suggest control applications--computers, automatic washing machines, machine tools, missiles and aircraft.

Y-002

Yen, K. T.

A THEORETICAL EVALUATION OF THE COANDA NOZZLE

Rensselaer Polytechnic Institute, Dept. Aero. Eng'g. Troy, New York, 1955

Y-003

Yerman, A. J., Bialous, A. J.

NEW DEVELOPMENTS IN PRESSURE AND FLOW MEASUREMENT TECHNIQUES

General Electric Report No. 58GL251, Sept..26, 1958

See author Bialous, A. J.

Z-001

Zalmanson, L. A., and Semikora, A. I.

INVESTIGATION OF THE CHARACTERISTICS OF PNEUMATIC JET ELEMENTS

Automation and Remote Control, Vol. 20, No. 4, April 1959, Page 431

See author Semikora, A. I.

Z-002

Zalmanzon, L. A. (Moscow)

SOME ASPECTS OF PNEUMATIC EXTREMUM CONTROLLER DESIGN

Automation and Remote Control, Page 93, January 1957

Conditions are indicated under which it is desirable to supplement controllers of normal type by automatic adjustment to the maximum or minimum of some quantity dependent on the controlled parameter. One possible way of doing this by means of pneumatic devices is considered; automatic adjustment is performed by a pneumatic device consisting of a pneumatic divider coupled to a system of parallel and intersecting pipes together with certain other units.

Z-003

Zerner, F., and Metral, A.

L'EFFECT COANDA

Publ. Sci. Min. Air., (218) (Ministry of Aviation Translation publication No. TIB/T4027), 1958

Z-004

Zeuner, K., Fuchs, A. M.

DIFFERENTIAL CAM FOLLOWER CONTROLS PNEUMATIC HYDRAULIC ACTUATOR

Control Engineering, Vol. 8, No. 1, Page 125, January 1961

Much of industrial control is rooted in 3 to 15 psi pneumatic hardware of high accuracy and reliability. But low response speed, inadequate position resolution, and excessive reaction to changes in load force may be encountered in such systems as force levels, strokes, and actuator speed requirements increase. A pneumatic-hydraulic positioning system has been designed which provides high power-level positioning capability for pneumatic control systems.

Z-005

Zisfein, M. B. (Giannini Controls Corp.)

#### ANALOG FLUID STATE DEVICES AND THEIR APPLICATION IN CONTROL SYSTEMS

Report No. ARD-06-010 Presented at SAE Committee A-6 Symposium on Fluid Amplifiers, Kansas City, Missouri, October 3, 1963

Fluid state components and systems are defined as those components and systems which perform any function or functions of control by means of a ducted fluid flowing as a free jet or an attached stream in passages or chambers free of moving mechanical parts or electronic interfaces. The fluid is frequently air or a hot gas, but it can also be a liquid. The functions performed by fluid state components can be any of the power or information processing functions normally encountered in control loops such as sensing, compensation or logical operations, amplification, and actuation.

Z-006

Zobel, T. H.

#### DEVELOPMENT AND CONSTRUCTION OF AN INTERFEROMETER FOR OPTICAL MEASUREMENT OF DENSITY FIELDS

NACA Tech. Memo No. 1184, 1947

Z-007

Zumwalt, G. W.

#### THE APPLICATION OF FREE JET MIXING THEORIES TO FLUID AMPLIFIER ELEMENTS

Proceedings of the Fluid Amplification Symposium, October 1962, Vol. I, DOFL, Washington, D. C.

Jet mixing analysis is not a new field. This paper examines the status of two well-accepted mixing theories, one laminar, and one turbulent, in order to (1) make immediate application where possible; (2) delineate inherent limitations, and (3) suggest profitable extensions of the theoretical treatments.